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INSECT PEST CONTROL AND YIELD PATTERNS IN CENTRAL QUEENSLAND COTTON CROPS

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E.M.N.

SUMMARY

During 1957-1960, six field trials were carried out mainly to investigate the status of *Heliothis armigera* (Hubn.) as a pest of cotton under a variety of agronomic conditions. Heavy fertilizer dressings and hormone applications were used to increase the potential yields of seed cotton per acre in both rain-grown and irrigated crops. Early-season control of *H. armigera* is shown to exert the same influence under all agronomic conditions encountered, i.e. higher early-pick yields with no increase in total yields.

In two trials in which severe infestations of *Pectinophora scutigera* Hold. were experienced, DDT applications resulted in considerably increased yields. Results of one trial indicated that relatively small populations of leaf-eating insects during the early and major square and boll production period can depress yields. Fertilizer is shown to have potential value in irrigated cotton, but the use of alpha naphthalene acetic acid sprays did not increase yields.

I. INTRODUCTION

Field trials during 1948-1957 demonstrated that *Heliothis armigera* (Hubn.) is not a pest of major economic importance during the early square and boll production period of cotton. The killing of Heliothis allowed the plants to hold a larger percentage of the early squares and bolls; thus sprayed cotton produced a greater early yield than unsprayed. Differences in later picks, however, were sufficient to give approximate equality in total yields (Passlow 1959).

The present work followed directly from these results. Six trials were carried out to test the validity of the above conclusions under a wide range of agronomic conditions. Plant reactions to pest kills were studied in five of the trials. Two (Trials 1 and 2, 1957-58) were established using standard agronomic practice, one with and one without supplementary irrigation; two (Trials 3 and 4, 1958-59), one with and one without supplementary irrigation, incorporated the use of heavy dressings of fertilizers and applications of alpha naphthalene acetic acid to prevent shedding of fruit forms; and two (Trials 5 and 6, 1959-60), both with supplementary irrigation, were carried out using heavy dressings of fertilizers.

The variety Miller 43-9-0 was used at Biloela, and Arkot 2-1 was planted in the rain-grown trials at Gracemere during the first two seasons and in the irrigated trial at Kabra in 1959-60. All trials were designed to give some insecticide cover during the major square and boll production period and to ascertain the value of this protection under the conditions operating in each trial.

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II. METHODS

Plot size varied among trials from 180 row-feet in Trials 5 and 6 to 396 row-feet in Trial 2. Plots of six yield rows were used in Trials 1, 2, 5 and 6 and of four yield rows in Trials 3 and 4. An inter-row spacing of 3 ft 6 in. was employed in all trials except Trial 6, where the spacing was 3 ft 9 in.

Heliothis egg counts were made weekly in each trial on 30 plant terminals per plot selected at random in six groups of five in Trials 1-4 and on 15 plant terminals per plot selected at random in five groups of three in Trials 5 and 6. A terminal was taken as that part of the plant from the growing point to the fifth leaf from the top.

Spray treatments were applied by power-driven twin-nozzle hand applicators and the materials used were:

DDT.—An emulsion concentrate containing 25 per cent. w/v active ingredient.

Endrin.—An emulsifiable preparation containing 20 per cent. w/v active ingredient.

Alpha naphthalene acetic acid.—A solution containing 2 per cent. w/v active ingredient.

Insecticides were applied during the eight weeks following the first burst of squaring to give protection from pest attack over this period of major square and boll production. The hormone was applied (in Trials 3 and 4) three weeks after the first burst of squaring, and in one treatment again three weeks later. Fertilizers were applied (in Trials 3-6) by hand as a basal preplant dressing, and as a side-dressing three weeks after the first burst of squaring. The basal dressing comprised 254 lb sulphate of ammonia, 400 lb superphosphate and 127 lb muriate of potash per acre, and the side-dressing 283 lb sulphate of ammonia per acre.

In all trials except Trial 6 some attention was given to plant behaviour in relation to pest control, and to fertilizer and hormone usage where applicable. Prior to the commencement of squaring, five plants (Trials 1 and 2) and four plants (Trials 3, 4 and 5) per plot were selected and weekly records of the numbers of squares, bolls and mature bolls were made. In addition, all fallen forms were collected weekly, counted and examined for insect damage, from two inter-row areas each 20 ft long per plot in Trials 1 and 2, from three inter-row areas each 14 ft long in Trials 3 and 4, and from four inter-row areas each 10 ft long in Trial 5. Numbers of larvae of the boll-feeding insects *Heliothis armigera* (Hubn.), *Earias huegeli* Rogen, *Pectinophora scutigera* (Hold.) and *Dichocrocis punctiferalis* (Guen.) were recorded.

Further weekly records of insect species found on the aboveground parts of two plants (in an observation row) per plot were made in Trial 5.

Trial layouts, details of treatments with insecticide and hormone dosages, and other relevant information are given with the results.

III. RESULTS

(a) Trial 1. 1957-58, Biloela. 3 x 7 Randomized Block. Irrigated

The trial was planted on October 15 and insecticide applications were made on November 26, December 11 and 24 and January 8 at 33, 37, 105 and 125 gal per ac respectively. Heliothis egg counts did not indicate differences for oviposition among treatments, and numbers of eggs exceeded 5 per 100 terminals only on November 19 and 26 and December 2, 11, 16 and 23, when 5·6, 13·2, 53·3, 16·5, 9·0 and 10·0 respectively per 100 terminals were recorded. Small numbers of *Anomis flava* F. were recorded during December and March, and *E. huegeli* and *P. scutigera* respectively caused only minor damage during January and from April until the end of the season.

TABLE 1

TRIAL 1. TOTAL AND DAMAGED FALLEN FORMS PER PLOT SITE

Treatment	Fallen Forms (Mean)	Damaged Fallen Forms (Mean)	Damaged Fallen Forms (%)	
			Transformed Mean	Equivalent Mean (%)
DDT 0·1% spray	532	114	27·6	21·5
Endrin 0·05% spray ..	483	129	31·2	26·8
Check	589	142	29·6	24·4
Necessary differences for significance 5%	64	18	2·2	
Necessary differences for significance 1%	89	25	3·0	

Fruit form production conformed to the usual pattern of higher total production on unsprayed than on sprayed plants. Numbers of fallen forms and percentage of damaged fallen forms are given in Table 1. Harvest was on March 10-12 and May 6-8 and yields are given in Table 2.

TABLE 2

TRIAL 1. YIELDS AND PLANTS PER PLOT, AND YIELDS AND BOLLS PER SITE

Treatment	Yield (lb/ac)		Plants per Plot	Yield per Site (lb)	Bolls per Site
	1st Pick	Total Pick			
DDT 0·1% spray	1,156	1,455	338	4·29	390
Endrin 0·05% spray ..	1,069	1,428	337	4·28	366
Check	878	1,334	329	3·95	364
Necessary differences for significance 5%	106	132	24	0·33	34
Necessary differences for significance 1%	149	184	34	0·47	48

The results, in which differences are apparent on the first pick without significant differences in total yield, are similar to those in earlier work (Passlow 1959).

(b) Trial 2. 1957-58, Gracemere. 3 x 7 Randomized Block. Rain-grown

The trial was planted on November 7 and insecticide applications were made on January 9 and 23 and February 6 and 25 at 83, 109, 110 and 120 gal per ac respectively. Heliothis populations as recorded in egg counts per 100 terminals were low throughout, with no differences among treatments. Between December 20 and January 28 the maximum was 4·8 eggs on January 6, and during a second period of oviposition between March 10 and April 21 a maximum of 12·1 eggs was recorded. Counts other than during these periods were fewer than one. Small numbers of *E. huegeli* larvae were recorded throughout the trial in fallen forms. Relatively larger numbers of *P. scutigera* larvae were recorded in fallen forms from late April until the end of the trial (the maximum from all fallen forms was 126 on June 3).

Following low Heliothis populations early in the season, no differences in production occurred during this period; however, from late March the DDT-treated plants produced fewer forms than plants in the other treatments. Numbers of fallen forms and percentage damaged fallen forms are given in Table 3. The high percentage of damaged fallen forms was the result of late-season attack by *P. scutigera.*

TABLE 3

TRIAL 2. TOTAL AND DAMAGED FALLEN FORMS PER PLOT SITE

Treatment	Fallen Forms (Mean)	Damaged Fallen Forms (Mean)	Damaged Fallen Forms (%)	
			Transformed Mean	Equivalent Mean (%)
DDT 0·1% spray	635	195	33·5	30·5
Endrin 0·05% spray ..	634	205	34·7	32·4
Check	651	217	35·3	33·4
Necessary differences for significance 5%	98	42	2·2	
Necessary differences for significance 1%	131	60	3·1	

Harvest was on March 24-27, May 12-15 and June 23-30. Data collected do not explain the yield difference (Table 4) obtained. Probably control by endrin of the relatively light infestation of *A. flava* and other leaf-eating insects encountered was responsible for these differences.

TABLE 4

TRIAL 2. YIELDS AND PLANTS PER PLOT, AND YIELDS AND BOLLS PER SITE

Treatment	1st Pick	1st + 2nd Picks	Total Pick	Plants per Plot	Yield per Site (lb)	Bolls per Site
DDT 0·1% spray ..	572	892	1,188	342	4·16	414
Endrin 0·05% spray ..	629	938	1,317	351	4·55	444
Check	530	815	1,140	351	3·73	396
Necessary differences for significance 5%	72	74	161	12	0·77	60
Necessary differences for significance 1%	101	103	226	17	1·08	85

(c) Trial 3. 1958-59, Biloela. 3 x 3 x 3 Factorial Design. Irrigated

The trial was planted on October 14. Fertilizer treatments were: F0, no fertilizer; F1, basal preplant dressing applied on October 14; and F2, basal dressing as in F1 plus a side-dressing applied at maximum squaring on December 22. Insecticide treatments were: D0, no insecticide; D1, four fortnightly DDT 0·1% spray applications from the first burst of squaring on December 9 and 23 and January 8 and 21; and D2, eight weekly DDT 0·1% spray applications from the first burst of squaring on December 9, 16 and 23 and January 2, 8, 14, 21 and 28. DDT was used at an average rate of 161 gal per ac. Hormone treatments were: H0, no hormone; H1, one application of a solution of alpha naphthalene acetic acid at 10 p.p.m. to wet all fruit forms at major square production on December 22; and H2, two applications of alpha naphthalene acetic acid at 10 p.p.m. used as in H1 on December 22 and January 14. The hormone was used at 124 gal per ac.

Heliothis egg counts did not suggest differences in oviposition among treatments, and numbers of eggs exceeded 5 per 100 terminals on November 18 and 25, December 3, 9, 17, 23 and 30 and January 6, when 14·2, 9·6, 6·7, 15·3, 43·1, 28·5, 24·4 and 20·2 were recorded. Some eggs of *A. flava* were noted on terminals during November (maximum number 29 on November 18) and few larvae of *E. huegeli* and *P. scutigera* were recovered from fallen forms.

Total numbers of fallen forms per plot and percentages of damaged fallen forms per plot are given in Table 5. Calculated total production of fruiting forms per plant and numbers of plants per plot are given in Table 6. Harvest was on March 9-11, March 24-25, April 27 and July 31 and yields are given in Table 7.

Both DDT and fertilizer usage resulted in increased yields. Yields after DDT applications followed the usual pattern when applied for protection of early squares and small bolls, i.e. considerable increases over check plots in the early picks, with the check plots outyielding treated plots in the late picks. The early differences, however, were greater than the late, giving significant differences among treatments.

Despite the egg counts recorded, Heliothis larvae were seldom noted during the trial (10 only being recorded from all fallen forms), and although 16 per cent. of fallen forms were damaged in check plots, compared with 5 per cent. and 7 per cent. in DDT-treated areas, there were no differences among either total numbers of fallen forms or fruit form production per plant. Yield differences, therefore, were not related to Heliothis control. A pest factor not covered by the data collected was obviously present in this trial.

TABLE 5

TRIAL 3. TOTAL AND PERCENTAGE DAMAGED FALLEN FORMS PER PLOT

Treatment	Total Fallen Forms			Damaged Fallen Forms					
				Transformed Mean			Equivalent Mean (%)		
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	1,344	1,876	2,301	24·5	23·1	22·5	17·2	15·3	14·6
D1	1,238	1,881	2,631	18·8	13·5	12·9	10·4	5·5	5·0
D2	1,243	1,932	2,565	15·0	11·6	11·7	6·7	4·1	4·1
	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	1,740	1,823	1,950	23·3	22·9	23·8	15·7	15·1	16·3
D1	1,986	1,828	1,936	14·7	15·2	15·3	6·4	6·9	6·9
D2	1,904	2,024	1,812	12·9	12·7	12·7	5·0	4·9	4·8
F0	1,253	1,212	1,359	19·0	19·7	19·5	10·6	11·4	11·1
F1	1,860	1,972	1,857	16·7	15·6	15·9	8·3	7·2	7·5
F2	2,516	2,491	2,489	15·2	15·5	16·3	6·8	7·1	7·9

Necessary differences for significance	Marginal	Individual	Marginal	Individual
5%	179	311	1·4	2·5
1%	272	471	2·2	3·7

Fertilizer applications increased yields proportionally to the amount of suphate of ammonia applied and irrespective of time of application. Yield patterns following DDT usage were not changed by applications of fertilizers.

Hormone applications did not significantly affect yields, although actual yields, particularly in the early picks, were lower where the hormone was applied than in the check treatment.

TABLE 6

TRIAL 3. TOTAL FRUIT FORM PRODUCTION PER PLANT AND PLANTS PER PLOT

Treatment	Total Fruit Form Production per Plant			Plants per Plot		
	F0	F1	F2	F0	F1	F2
D0	26·4	38·0	48·0	399	406	407
D1	27·7	38·1	45·5	399	396	415
D2	27·0	37·9	48·7	400	404	402
	H0	H1	H2	H0	H1	H2
D0	40·0	37·1	35·2	401	400	411
D1	38·7	34·0	38·7	404	406	400
D2	38·9	39·4	35·3	401	413	392
F0	30·5	26·8	23·8	390	411	398
F1	36·9	39·8	37·3	406	403	396
F2	50·2	43·9	38·1	410	404	410
	Marginal	Individual				
Necessary differences for significance 5%	2·3	4·0		No significant differences		
Necessary differences for significance 1%	3·5	6·0				

(d) Trial 4. Gracemere, 1958-59. 3 x 3 x 3 Factorial Design. Rain-grown

The trial was planted on December 8-9. The treatments applied were the same as in Trial 3: F1, basal preplant dressing on December 8-9; F2, basal dressing on December 8-9 and side-dressing at maximum squaring on February 11; D1, four fortnightly DDT 0·1% sprays on January 29, February 12 and 26 and March 13; D2, eight weekly DDT 0·1% sprays on January 29, February 5, 12, 20 and 26 and March 5, 13 and 19; H1, alpha naphthalene acetic acid applied at major square production on February 12; H2, alpha naphthalene acetic acid applied as for H1 on February 12 and on March 5. DDT was used at an average rate of 128 gal per ac and the hormone at an average rate of 165 gal per ac.

Egg counts suggested that ovipositing Heliothis moths had a slight preference for oviposition sites on terminals within D2 and F2 treatments. Mean counts exceeded 5 eggs per 100 terminals on only January 20, February 5, February 25

TABLE 7

TRIAL 3. YIELDS PER PLOT (lb/ac)

Treatment	1st Pick			1st plus 2nd Pick			1st plus 2nd plus 3rd Pick			Total Pick		
	F0	F1	F2	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	753	839	731	1,167	1,681	1,553	1,428	2,268	2,673	1,640	2,448	2,830
D1	1,117	786	1,059	1,746	1,846	2,210	1,950	2,386	3,152	2,102	2,447	3,266
D2	757	1,157	1,357	1,547	2,210	2,691	1,851	2,559	3,311	1,995	2,677	3,487
	H0	H1	H2	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	926	690	708	1,667	1,362	1,372	2,275	2,085	2,008	2,448	2,275	2,195
D1	989	1,070	994	1,867	1,987	1,948	2,489	2,466	2,515	2,591	2,579	2,645
D2	1,164	1,154	953	2,227	2,179	2,042	2,662	2,587	2,472	2,795	2,745	2,620
F0	831	904	893	1,529	1,522	1,409	1,802	1,801	1,626	1,949	1,973	1,815
F1	1,124	852	805	2,112	1,781	1,845	2,529	2,265	2,401	2,656	2,408	2,508
F2	1,033	1,158	957	2,121	2,226	2,108	3,095	3,073	2,969	3,229	3,218	3,136
	Marginal	Individual		Marginal	Individual		Marginal	Individual		Marginal	Individual	
Necessary differences for significance 5%	220	380		201	349		162	280		154	267	
Necessary differences for significance 1%	333	576		305	528		245	425		233	404	

TABLE 8

TRIAL 4. TOTAL AND PERCENTAGE DAMAGED FALLEN FORMS PER PLOT AND TOTAL FRUIT FORM PRODUCTION PER PLANT

Treatment	Total Fallen Forms			Damaged Fallen Forms (%)						Total Fruit Form Production per Plant		
				Transformed Mean			Equivalent Mean (%)					
	F0	F1	F2	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	945	1,544	1,502	31·7	34·7	34·1	27·7	32·4	31·5	14·7	25·3	28·2
D1	973	1,241	1,359	27·2	26·2	27·7	20·9	19·4	21·6	17·3	21·8	23·8
D2	1,083	1,080	1,183	20·0	23·6	24·0	11·7	16·0	16·6	18·6	21·9	20·7
	H0	H1	H2	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	1,126	1,395	1,470	32·0	33·9	34·6	28·1	31·1	32·3	17·2	25·3	25·6
D1	1,283	1,199	1,091	25·1	25·8	30·2	18·0	18·9	25·3	25·5	17·8	19·6
D2	1,174	1,073	1,099	21·5	21·7	24·4	13·4	13·6	17·1	21·2	19·4	20·7
F0	1,031	1,002	967	25·1	26·0	27·9	18·0	19·2	21·9	18·3	15·1	17·1
F1	1,247	1,279	1,339	26·9	28·1	29·4	20·4	22·2	24·1	22·5	23·2	23·3
F2	1,305	1,387	1,353	26·6	27·3	32·0	20·1	21·0	28·0	23·1	24·1	25·4
	Marginal	Individual		Marginal	Individual					Marginal	Individual	
Necessary differences for 5% significance	270	468		3·0	5·3					3·1	5·4	
Necessary differences for 1% significance	409	709		4·6	8·0					4.7	8·2	

and March 4, when 17·3, 15·8, 19·5 and 9·0 eggs per 100 terminals were recorded. Few eggs and larvae of *A. flava* and *E. huegeli* were observed during the trial. Larvae noted in fallen forms were predominantly *P. scutigera.* Population differences among treatments were obvious (Figure 1).

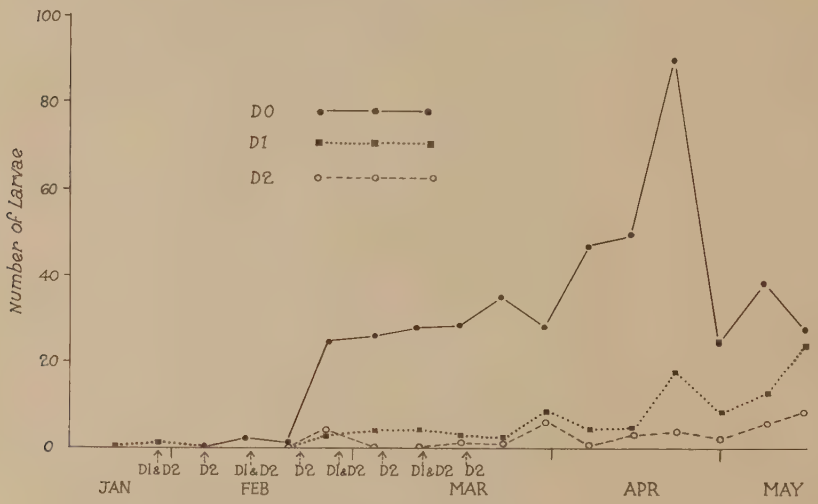

Fig. 1—*Pectinophora scutigera* larvae in fallen forms. Trial 4, 1958-59.

Total numbers of fallen forms per plot, percentages of damaged fallen forms per plot and calculated total production of fruiting forms per plant are given in Table 8.

Harvest was on April 21-24 and May 11-13 and yields together with numbers of plants per plot are given in Table 9.

As *P. scutigera* damage was severe in this trial, an assessment of damage on mature unpickable bolls (bolls mature without any pickable cotton) was carried out on April 28. All unpickable mature bolls were collected from sufficient plants to give 50 bolls and these bolls were examined for evidence of insect attack. Virtually all larvae recorded were *P. scutigera.* Numbers of unpickable bolls per plant and percentages of unpickable bolls damaged by insects are given in Table 10.

Relatively low Heliothis populations were experienced in this trial and any effect which these insects may have had was masked by severe attack by the pink bollworm, *P. scutigera.* The spectacular increases obtained from four fortnightly and eight weekly applications of DDT indicate the value of this insecticide in preventing damage from *P. scutigera.* Weekly applications gave better yields than DDT used at fortnightly intervals. As, however, detailed

TABLE 9

TRIAL 4. YIELDS PER PLOT (lb/ac) AND PLANTS PER PLOT

Treatment	Yields						No. of Plants per Plot		
	1st Pick			Total Pick					
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	496	486	393	663	724	650	557	480	438
D1	869	1,064	1,043	1,116	1,431	1,326	537	514	533
D2	1,186	1,245	1,367	1,522	1,592	1,718	573	468	511
	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	571	372	432	825	583	628	520	473	482
D1	1,215	912	850	1,524	1,255	1,093	519	547	517
D2	1,274	1,287	1,237	1,630	1,597	1,605	502	497	553
F0	952	846	753	1,200	1,093	1,008	541	555	571
F1	1,088	823	884	1,395	1,110	1,242	470	463	529
F2	1,020	903	881	1,385	1,232	1,076	530	500	453
	Marginal	Individual		Marginal	Individual		Marginal	Individual	
Necessary differences for significance 5%	127	220		155	268		37	64	
Necessary differences for significance 1%	192	333		234	406		56	97	

TABLE 10

TRIAL 4. UNPICKABLE BOLLS PER PLANT AND PERCENTAGE DAMAGED

Treatment	No. of Unpickable Bolls per Plant			Unpickable Bolls Insect Damaged (%)					
				Transformed Mean			Equivalent Mean (%)		
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	0·93	2·54	2·06	72·3	81·9	77·1	90·7	98·0	95·0
D1	0·61	0·77	1·31	66·0	70·5	73·5	83·5	88·8	91·9
D2	0·30	0·57	0·47	61·2	63·4	65·4	76·8	80·0	82·7
	H0	H1	H2	H0	H1	H2	H0	H1	H2
D0	1·17	2·31	2·05	75·7	79·1	76·4	93·9	96·9	94·5
D1	0·77	0·80	1·11	68·6	68·3	73·0	86·7	86·3	91·5
D2	0·52	0·38	0·44	66·2	60·3	63·5	83·7	75·5	80·1
F0	0·61	0·68	0·54	66·7	64·1	68·7	84·3	81·0	86·8
F1	0·97	1·61	1·30	75·7	67·7	72·3	93·9	85·6	90·8
F2	0·88	1·19	1·75	68·1	75·9	71·9	86·1	94·1	90·4
	Marginal	Individual		Marginal	Individual				
Necessary differences for significance 5%	0·47	0·81		4·6	7·9				
Necessary differences for significance 1%	0·71	1·22		6·9	12·0				

observations on *P. scutigera* populations were not carried out, the results do not indicate the numbers of treatments required for economic control of the pest. Pest populations at harvest suggest that treatments later in the season may have further increased yields.

Response to fertilizer application was not obtained in this rain-grown trial although more fruit forms were produced. As overall seasonal conditions were somewhat drier than usual, this result was not unexpected. Apparently nitrogenous fertilizers are of value in rain-grown crops only when available moisture at critical periods approaches that of crops grown with supplementary irrigation.

The decrease in yields following hormone usage suggested in Trial 3 was obtained in this trial. As total yields in both treatments where hormone was applied were approximately equal, the loss of yield potential was associated chiefly with the application on February 12. Two explanations of this behaviour are possible: (1) production of squares may have been depressed (although a depression was not obtained in total cumulative production, production during the week ending February 18 was lower than in the check treatment) and (2) hormone application caused the fall of small squares which were not recovered in fallen form collections.

(e) Trial 5. 1959-60, Biloela. 9 x 3 Randomized Block. Irrigated

The trial was planted on October 7. Treatments were all combinations of three fertilizer rates—F0, F1 and F2 as in Trials 3 and 4 with dressings on October 7 and November 23—and three DDT treatments—D0, no insecticide, D1, four 0·1% applications during the second month after the first burst of squaring with treatments on January 6, 13 and 27 and February 3, and D2, four fortnightly 0·1% applications from the first burst of squaring with treatments on December 8 and 23 and January 6 and 27. DDT was used at an average rate of 176 gal per ac.

Egg counts indicated low Heliothis populations throughout the trial. Egg numbers exceeded 4 per 100 terminals only on November 30, December 7, 14 and 22 and January 5, when 4·7, 13·3, 6·4, 9·1 and 6·9 were recorded respectively. Few other insects were recorded on terminals: occasional Heliothis larvae were noted in fallen forms during January; larvae of *E. huegeli* were recorded during the January-April period but not in pest proportions; *P. scutigera* larvae, however, caused damage, considerable numbers being recovered during early January and March-April (Figure 2). In weekly observations of insect species on two plants in an observation row in each plot, small numbers of *Aulacosternum nigrorubrum* Dall., *A. flava, Bucculatrix gossypii* Turn., *Dysdercus sidae* Montr. and *Tectocoris diophthalmus* (Thunb.) were recorded. The only insects noted in high populations were *P. scutigera* and *Oxycarenus luctuosus* Montr., 10-20 of the latter being recorded per plant during late February and March.

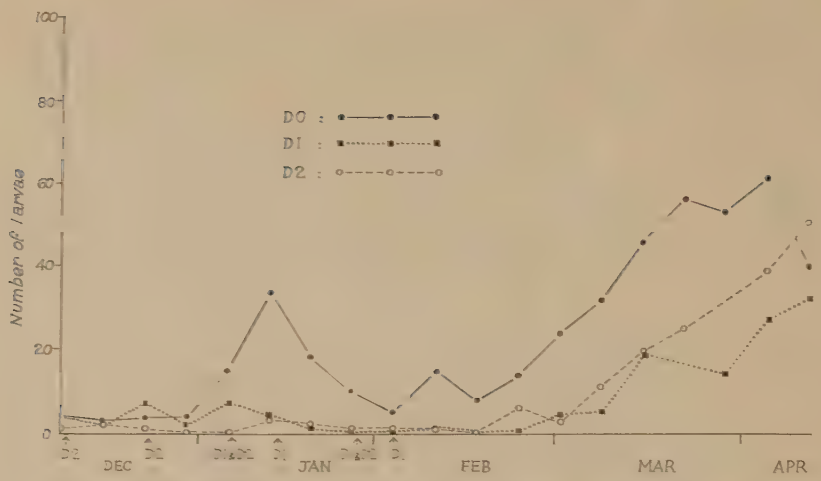

Fig. 2—*Pectinophora scutigera* larvae in fallen forms. Trial 5, 1959-60.

Total numbers of fallen forms per plot and percentages of damaged fallen forms are given in Table 11. Calculated total production of fruit forms per plant and the percentage of mature bolls damaged on plants in observation rows are given in Table 12.

Harvest was on March 9-10 and April 12-13 and yields together with number of plants per plot are given in Table 13.

Yields were low in this trial following a severe angular leaf spot (*Xanthomonas malvacearum* (E. F. Smith) Dowson) attack during December, and mid-season and late season damage from *P. scutigera*. Cumulative weekly records of mature damaged bolls (Table 12) indicate the severity of *P. scutigera* attack.

Heliothis populations were low throughout the season and had no influence on final yields.

TABLE 11

TRIAL 5. TOTAL AND PERCENTAGE DAMAGED FALLEN FORMS PER PLOT

Treatment	Total Fallen Forms			Damaged Fallen Forms (%)					
				Transformed Mean			Equivalent Mean (%)		
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	1,799	2,326	3,215	23·57	22·50	22·40	16·0	14·6	14·5
D1	1,848	2,226	2,867	18·97	16·77	16·93	10·6	8·3	8·5
D2	1,778	2,316	3,163	16·00	12·93	16·17	7·6	5·0	7·8

	Marginal	Individual	Marginal	Individual
Necessary differences for 5% significance	290	502	1·41	2·45
Necessary differences for 1% significance	400	692	1·95	3·37

TABLE 12

TRIAL 5. TOTAL FRUIT FORM PRODUCTION PER PLANT AND PERCENTAGE MATURE BOLLS DAMAGED

Treatment	Fruit Form Production			Mature Bolls Damaged (%)		
	F0	F1	F2	F0	F1	F2
L0	20·3	27·3	36·3	50·0	41·9	23·1
D1	20·6	27·1	35·7	14·3	13·6	11·8
D2	19·2	29·1	37·8	13·8	18·5	8·3
	Marginal		Individual			
Necessary differences for significance 5%	3·2		5·6	No analysis		
Necessary differences for significance 1%	4·4		7·7			

Fertilizer applications significantly increased yields but the increases obtained were considerably lower than anticipated, much of the fertilizer advantage being lost in reduced potential fruit form production following the disease outbreak.

(f) Trial 6. 1959-60, Kabra. 9 x 3 Randomized Block. Irrigated

The trial was planted on October 21. Treatments were combinations of three fertilizer levels as in Trial 5, with dressings on October 21 and January 4, and three DDT treatments: D0, no insecticide; D1, two applications of DDT on January 25 and February 1, commencing one month after the first burst of squaring, and D2, three applications of DDT on December 21, January 4 and January 25, commencing at the first burst of squaring. DDT was used at an average rate of 188 gal per ac.

Egg counts indicated low Heliothis populations throughout the trial period, numbers exceeding 4 per 100 terminals on only December 16 and February 8, when 6·2 and 4·4 were recorded respectively. The only insects noted in more than small numbers during the trial were *Aphis gossypii* Glov. and *Austroasca terrae-reginae* (Paoli). Both were active during early December, the former causing little damage, the latter causing severe foliage injury in some areas of the trial. This injury, however, was not permanent, affected areas being indistinguishable from the remainder of the trial by early January.

Detailed records of fruit form production and loss were not taken from this trial.

Harvest was carried out in four picks—February 22-March 3, March 3-8, March 19 and April 4-6. Yields are given in Table 14. Mean stand of plants per plot and total yields adjusted to an equal number of plants per plot are given in Table 15.

TABLE 13

TRIAL 5. YIELD (LB/AC) AND PLANTS PER PLOT

Treatment	Yield						No. of Plants per Plot		
	1st Pick			Total Pick					
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	901	1,155	1,028	1,088	1,399	1,383	535	527	524
D1	1,157	1,143	1,286	1,341	1,788	1,802	523	529	519
D2	1,062	1,528	1,417	1,180	1,770	1,756	533	522	541
	Marginal	Individual		Marginal	Individual				
Necessary differences for significance 5%	200	347		224	388		No significance difference		
Necessary differences for significance 1%	276	478		309	535				

TABLE 14

TRIAL 6. YIELD (LB/AC)

Treatment	1st plus 2nd Pick			1st plus 2nd plus 3rd Pick			Total Yield (Four Picks)		
	F0	F1	F2	F0	F1	F2	F0	F1	F2
D0	1,880	2,059	1,813	2,405	2,758	2,652	2,603	3,035	2,981
D1	2,257	1,932	1,706	2,583	2,674	2,474	2,704	3,012	2,953
D2	1,624	2,108	1,329	2,235	2,870	2,398	2,543	3,179	3,126
	Marginal	Individual		Marginal	Individual		Marginal	Individual	
Necessary differences for significance 5%	337	584		365	632		385	667	
Necessary differences for significance 1%	465	805		503	871		531	919	

TABLE 15

TRIAL 6. MEAN STAND PER PLOT AND ADJUSTED YIELDS (LB/AC)

Treatment	Mean Stand			Adjusted Yield		
	F0	F1	F2	F0	F1	F2
D0	524	424	450	2,330	3,151	2,997
D1	562	398	416	2,283	3,229	3,101
D2	456	482	373	2,534	3,070	3,440
	Marginal	Individual		Marginal	Individual	
Necessary differences for significance 5%	83	144		218	377	
1%	115	199		301 (approx.)	522	

IV. DISCUSSION AND CONCLUSIONS

Results of Trials 1 and 2 confirm the conclusions drawn from earlier work that Heliothis populations during the early square and boll formation period do not warrant insecticide control. The significant increase which followed the use of endrin in Trial 2 suggests that control of relatively small populations of leaf-eating insects, such as *Anomis flava,* is of value during the early and major square and boll production period.

Yield patterns were according to the usual pattern in Trial 3, while in Trial 4 any results from Heliothis control were masked by the severe attack of *P. scutigera.* In Trial 5, the black arm phase of angular leaf spot and *P. scutigera* exerted a much greater influence on yields than *H. armigera.* Pest incidence was so low in Trial 6 that yield differences due to insecticides could not be expected.

Trial 4 (rain-grown) indicates that fertilizer application in the absence of sufficient moisture is not worthwhile. On the other hand, the use of fertilizer with adequate irrigation, at the heavy applications made, gives economic returns (Trial 3) in the absence of complicating factors. Fertilizer response was minimized by black arm and *P. scutigera* damage in Trial 5, and in Trial 6 boll rots resulting from a severe storm causing lodging reduced yields by an estimated 500 lb per ac in the more heavily fertilized plots.

Applications of alpha naphthalene acetic acid to arrest the shedding of squares and small bolls in Trials 3 and 4 were not successful. Yields tended to be reduced where the hormone was applied, particularly in the rain-grown trial. This result indicates that if hormone applications are of value in cotton, timing is critically important. In India, on the other hand, Negi and Singh (1956) and Anon. (1958) obtained considerable yield increases following applications of alpha naphthalene acetic acid with similar timing and dosage.

The results of these trials indicate that Heliothis as an early-season pest is not of major importance in either rain-grown or irrigated cotton irrespective of the potential yield pattern. *P. scutigera* attacks, however, can reduce yields severely, and leaf-eating insects in relatively small populations are of economic concern in irrigated crops with high potential yields.

V. ACKNOWLEDGEMENTS

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EFFECT OF NEMATOCIDES ON THE HALIDE CONTENT AND BURNING TIME OF FLUE-CURED TOBACCO LEAF IN SOUTH QUEENSLAND

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SUMMARY

Five nematocides were studied under field conditions to determine efficacy in controlling the root-knot nematode *Meloidogyne javanica* (Treub) and influence on the halide content and burning time of flue-cured leaf of the variety Hicks.

DD and EDB gave a high level of nematode control and were consistently superior to "Vapam" and EN18133 (0,0 diethyl 0-2 pyrazinyl phosphorothioate). EN28450 (2-allylthio-2-thiazoline) was ineffective.

Soil treatment with EDB resulted in a marked increase in the bromine content of the cured leaf.

The chloride content of the leaf was increased following soil treatment with non-halogenated as well as halogenated chemicals. The levels were higher in leaf from plots treated with DD and EDB, and in two trials were sufficient to reduce the burning time.

I. INTRODUCTION

In Queensland the high chloride content of tobacco leaf, particularly from the Burdekin and Inglewood districts, has been the cause of much concern. Although the chloride contents of soils and irrigation waters are the most important considerations, several overseas workers (Neas 1959; McCants, Skogley, and Woltz 1959) have reported that the use of soil fumigants aggravates the problem. The increase in halide uptake appears to be due in part to the addition of halide ions to the soil solution and in part to the suppression of nitrification.

During the 1960-61 season three field trials were carried out on farms in the Beerwah-Glasshouse Mountains district to screen DD, EDB, and three non-halogenated compounds against the root-knot nematode *Meloidogyne javanica* (Treub), and compare their relative effects on the halide content and burning time of the cured leaf. The variety Hicks was used. Trials 1 and 3 were on land treated with EDB for the 1959-60 season and Trial 2 on land not previously fumigated.

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II. MATERIALS AND METHODS

The chemicals used were—

EDB.—Ethylene dibromide in power kerosine. EDB (sp.gr. 25/25 2·17) content 12·5 per cent. v/v.

DD.—A mixture of 1,3 dichloropropene and 1,2 dichloropropane containing 50-59 per cent. of total chlorine; inert compounds not exceeding 1 per cent. by weight.

EN18133.—0,0-diethyl 0-2-pyrazinyl phosphorothioate as a 5 per cent. granular formulation.

EN28450.—2-allylthio-2-thiazoline as a 20 per cent. granular formulation in Trials 1 and 2, and as an 80 per cent. emulsifiable concentrate in Trial 3.

"Vapam".—A water solution containing 5 lb sodium N-methyl dithiocarbamate per gal.

A 10 x 4 randomized block layout was used with the following treatments:

1. "Vapam"—25 gal/ac
2. EDB—20 gal/ac
3. DD—20 gal/ac
4. EN28450—15 lb a.i./ac
5. EN28450—25 lb a.i./ac
6. EN28450—35 lb a.i./ac
7. EN18133—5 lb a.i./ac
8. EN18133—10 lb a.i./ac
9. Untreated
10. Untreated

The soil was irrigated prior to treatment. "Vapam", EDB, DD and EN28450 (liquid) were applied by hand injector at a depth of 6 in. in holes 1 ft apart. EN18133 and EN28450 (granular) were applied by hand in a band 9 in. wide 3 in. beneath the intended plant line.

Tobacco plants were grown 18 in. apart with a 4 ft row interspace. There were 30 datum plants per plot.

Heights of 14 plants per plot were measured. One ripe leaf from each of 12 plants per plot was picked and flue-cured prior to halide analyses. When harvesting had been completed, 12 plants in each plot were dug and rated for root-knot nematode infestation. Root-knot indices (0-100) were calculated from the ratings (after Smith and Taylor 1947). Dates of field operations are given in Table 1.

For halide analyses the flue-cured leaves were dried to constant weight in a forced-draft oven at 40°C.

TABLE 1

DATES OF FIELD OPERATIONS

Operation	Trial 1	Trial 2	Trial 3
DD and EDB application	Sept. 12	Sept. 15	Sept. 16
" Vapam " application	Sept. 12	Sept. 15	Sept. 15
EN18133 application	Sept. 22	Sept. 28	Sept. 29
EN28450 application	Sept. 22	Sept. 28	Oct. 11
Planting	Oct. 4	Oct. 6	Oct. 11
Height measuring	Jan. 10	Jan. 10	Jan. 10
Leaf sampling	Jan. 25	Jan. 18	Jan. 18
Root-knot rating	Feb. 15	Feb. 15	Feb. 15

Chloride* was determined on a suspension of 1g oven-dried and powdered leaf sample in approximately 200 ml distilled water by titration with standard silver nitrate solution, using the method of Best (1929).

Bromine was determined by ashing the oven-dried and powdered leaf sample under alkaline conditions (Dudley 1939) at constant furnace temperature (450°C); the ash was extracted with hot distilled water and the extract treated with chromic acid solution of controlled strength. Under these conditions, bromine compounds were oxidised to bromine, which, on being passed through potassium iodide solution, liberated iodine quantitatively. The iodine was estimated by titration with N/100 sodium thiosulphate.

Burning time was taken as the time the flue-cured leaf, dried to a constant weight in a forced-draught oven at 100°C, continued to glow after being started with an electrically heated nichrome wire. The determination was made near the centre of the leaf, half-way between the midrib and the leaf margin. Figures given in Table 4 are the average of 12 determinations, one on each leaf of the sample.

III. RESULTS

The results are presented in Tables 2-6.

"Vapam" at 20 gal/ac gave a low level of root-knot nematode control. Plant growth was improved. Changes in leaf halides were not significant. Burning time was reduced in Trial 2.

EDB (12½% v/v) at 20 gal/ac gave a high level of root-knot nematode control. Plant growth was good. The bromine content of leaf from untreated plots was higher in Trials 1 and 3, which had been fumigated with EDB in the previous season. The chloride content was increased in each trial. Burning time was reduced by EDB in Trial 2.

* A proportion of the bromine in cured leaf is present as inorganic bromides. As silver nitrate tends to precipitate bromide ions before chloride ions, chloride analyses for the EDB-treated plots would be slightly high, less than 10 per cent. of the reported figure being bromine. For the other plots, the amount of bromine present would be insufficient to affect the figure for chloride content.

DD at 20 gal/ac gave the highest level of nematode control in the three trials. Plant growth was good. The bromine content of the cured leaf was not increased but there was a marked increase in the chloride content. In Trials 1 and 2, fumigation with DD reduced the burning time.

EN28450 was ineffective as a nematocide. Plant growth was very poor.

EN18133 (10 lb/ac) controlled root-knot nematodes but was inferior to DD and EDB. Changes in leaf halide and burning time were not significant.

TABLE 2

ROOT-KNOT INDICES

Chemical	Rate per Acre	Root-knot Index		
		Trial 1	Trial 2	Trial 3
"Vapam"	25 gal	68·4	92·2	40·8
EDB	20 gal	9·8	67·2	29·5
DD	20 gal	8·4	35·8	16·1
EN28450	15 lb	62·5	95·2	98·2
EN28450	25 lb	65·8	96·4	98·8
EN28450	35 lb	53·9	90·5	97·0
EN18133	5 lb	50·9	83·3	52·4
EN18133	10 lb	23·5	61·9	36·0
Untreated	..	82·0	97·9	97·9
Necessary differences for significance 5%	..	17·8	15·5	12·0
Necessary differences for significance 1%	..	24·0	20·9	16·1

TABLE 3

HEIGHTS OF TOBACCO PLANTS

Chemical	Rate per Acre	Average Height (cm)		
		Trial 1	Trial 2	Trial 3
"Vapam"	25 gal	84·3	136·5	100·6
EDB	20 gal	95·9	151·5	102·9
DD	20 gal	89·5	164·2	85·1
EN28450	15 lb	54·2	113·0	53·7
EN28450	25 lb	58·7	132·0	51·0
EN28450	35 lb	55·4	117·8	41·2
EN18133	5 lb	75·9	111·8	87·5
EN18133	10 lb	81·6	134·2	105·4
Untreated	..	66·8	109·0	50·4
Necessary differences for significance 5%	..	16·7	28·5	22·4
Necessary differences for significance 1%	..	22·5	38·5	30·2

TABLE 4

BURNING TIME OF CURED LEAF

Chemical	Rate per Acre	Burning Time (sec)		
		Trial 1	Trial 2	Trial 3
"Vapam"	25 gal	4·6	2·5	5·3
EDB	20 gal	3·4	1·9	3·4
DD	20 gal	2·1	1·1	4·7
EN18133	5 lb	3·3	3·0	6·2
EN18133	10 lb	3·7	4·0	5·8
Untreated	..	4·7	5·8	3·8
Necessary differences for significance 5%	..	1·7	1·7	2·4
Necessary differences for significance 1%	..	2·3	2·4	3·4

TABLE 5

BROMINE CONTENT OF CURED LEAF

Chemical	Rate per Acre	Bromine Content (p.p.m. Br)		
		Trial 1	Trial 2	Trial 3
"Vapam"	25 gal	282	90	68
EDB	20 gal	2,825	3,642	1,315
DD	20 gal	382	92	108
EN18133	5 lb	300	12	57
EN18133	10 lb	275	112	292
Untreated	..	182	18	98

TABLE 6

CHLORIDE CONTENT OF CURED LEAF

Chemical	Rate per Acre	Chloride Content (% Cl)		
		Trial 1	Trial 2	Trial 3
"Vapam"	25 gal	0·76	1·22	0·42
EDB	20 gal	1·40	1·79	0·76
DD	20 gal	1·33	2·54	0·77
EN18133	5 lb	1·10	1·04	0·35
EN18133	10 lb	0·88	1·30	0·63
Untreated	..	0·84	1·00	0·24
Necessary differences for significance 5%	..	0·30	0·59	0·34
Necessary differences for significance 1%	..	0·41	0·82	0·47

IV. DISCUSSION

It is unlikely that fumigation with EDB or DD to control nematodes in Queensland tobacco fields will be superseded in the near future. Cultural practices for nematode control such as the early ploughing out of infested roots, summer fallow and crop rotation can only be regarded as supplements to fumigation and not as substitutes, especially on areas where tobacco is grown every year.

The bromine content of leaf from plots not treated with EDB was higher in Trials 1 and 3 than in Trial 2. The sites of Trials 1 and 3 had been fumigated with EDB in the 1959-60 season, whereas the site of Trial 2 had not been treated. This suggests that the continued use of EDB may result in increasing levels of leaf bromine.

The marked increase in leaf chloride in plots treated with EDB and lower increases in plots treated with non-halogenated nematocides indicate that the main effect is probably exercised through the action on nitrification.

The effect of fumigation on nitrification is of a temporary nature (Tam 1945) and the need for studies to determine the effect of time of fumigation on halide uptake is indicated.

V. ACKNOWLEDGEMENTS

Mr. P. B. McGovern (Senior Biometrician) carried out the statistical analyses. Mr. D. Ironside (Field Assistant) was associated with all trials. This assistance is gratefully acknowledged.

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INVESTIGATIONS INTO THE CONTROL OF SUPERFICIAL SCALD IN COOL-STORED QUEENSLAND GROWN GRANNY SMITH APPLES BY CHEMICAL MEANS

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SUMMARY:

Experiments were conducted over a 5-year period to determine whether superficial scald in Queensland grown and cool-stored Granny Smith apples could be controlled by chemical means.

Diphenylamine applied prior to storage either as a dip or incorporated in paper wraps effectively controlled scald over a wide range of maturities and under conditions of normal atmosphere and controlled atmosphere storage.

Scald control was effected even in atmospheres containing high concentrations of carbon dioxide, but when 10 per cent. carbon dioxide was present in the storage atmosphere, oiled paper wraps containing 15 per cent. mineral oil in addition to the diphenylamine treatment were necessary to obtain complete control.

Low concentrations of diphenylamine in addition to oiled paper wraps containing 15 per cent. mineral oil yielded control of the disorder equal to higher concentrations of the compound used alone.

Though control was effected irrespective of the maturity of the fruit at the time of picking, other storage disorders increased if very immature fruit was stored.

Diphenylamine appeared to have some control on the incidence of internal breakdown in the experimental fruit.

A number of other chemical compounds were tested for their scald-controlling properties and five were found to give a considerable measure of control.

I. INTRODUCTION

The most common disorder associated with the cool storage of the Granny Smith apple variety is a superficial browning of the skin called superficial scald. This disorder in Australian-grown apples has been described by Carne (1948) and in the Granny Smith variety was the subject of a histological study by Bain (1956), who found that only two or three layers of cells are affected. Its control in susceptible American varieties was investigated by Brooks, Cooley, and Fisher (1923), who discovered that wrapping the fruit in paper containing more than 15 per cent. of a high-grade mineral oil resulted in good control. This method was adopted commercially and is still used extensively with both Australian and overseas varieties of apples. Extensive additional investigations have been carried out throughout the world and the results have been reviewed by a number of workers, including Martin (1957) and Fidler (1959). Despite all the information obtained, the cause of the disorder remains unknown.

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Fidler (1956) investigated the effect of weather during the period of growth of the English-grown Edward VII variety over a 10-year period and found that from measurements of rainfall or sunshine it should be possible to predict whether scald would be absent or slight, moderate or severe. Tindale and Huelin (1939) and Padfield (1954) reported that delays between harvesting and storage considerably reduced the incidence of superficial scald in Granny Smith apples, but Stevenson (1957) showed that while scald incidence was reduced, delays caused increased susceptibility to other defects such as mould and soggy breakdown. Melville and Hardisty (1953) reported that scald in Granny Smith apples could be controlled by a reduction in storage temperature from 40°F after four weeks' storage to 32°F, but Padfield (1958) found that this method did not aid scald control on New Zealand Granny Smith apples stored for seven months.

Superficial scald has been found to be severe in early-picked fruit, and Tindale and Huelin (1939), Padfield (1950) and Stevenson (1957, 1959) have shown that later picking dates result in a considerable reduction of the disorder.

When controlled atmosphere storage methods are employed with the Granny Smith variety there is an increase in the amount of superficial scald with increase in the amount of carbon dioxide present in the storage atmosphere (Huelin and Tindale 1947; Stevenson 1957).

The most important discovery with respect to the control of this disorder was the treatment of apples, prior to storage, with dips containing diphenylamine (DPA) in low concentrations (Smock 1955). The effectiveness of diphenylamine as a means of controlling scald in the Granny Smith variety was soon demonstrated by Australian workers and by Padfield (1959) in New Zealand.

The work of Abood and Gerard (1953) on cytochrome oxidase suggested to Smock that control might be affected by diphenylamine, and the possible involvement of oxidative enzymes in scald incidence was later discussed by Smock (1957). Subsequent work by Patterson (1959) has shown that some enzyme systems seem to be involved, as he obtained control by hot-water blanching, and that anti-oxidants prevent scald after removal of the fruit from store.

In view of the promising results obtained by Smock with diphenylamine, investigations were commenced in Queensland in 1956 to determine the effect of this compound and a number of other anti-oxidants on superficial scald incidence on the Granny Smith variety grown on the Granite Belt, surrounding Stanthorpe, and held under refrigerated conditions in air and controlled atmosphere storage.

Most of the subsequent experiments were concerned with testing materials that might be more acceptable to public health authorities than DPA. Particular attention was given to other oxidase inhibitors. Efforts were also made to determine the lowest effective concentration of DPA. The effect of DPA on scald development in fruit picked over a wide range of maturity was given attention in several experiments.

Picking dates were varied from late February to late April; fruit picked later than the middle of April is not usually susceptible to superficial scald.

II. 1956 EXPERIMENT

Objective.—To assess the effect of diphenylamine on the control of superficial scald in fruit picked at two different stages of maturity and held in different storage atmospheres.

Fruit.—The experimental fruit was obtained from four orchards. The picking dates were April 9 and April 23.

Pre-storage Treatments.—Three treatments were used:

(1) Oiled paper wraps containing 15% mineral oil
(2) 1000 p.p.m. DPA in 35% ethyl alcohol dip
(3) Oiled paper wraps containing 15 per cent. mineral oil plus a 1000 p.p.m. DPA in 35% ethyl alcohol dip.

Storage and Post-storage.—The fruit was stored in eighteen 44 gal wide-mouthed, gastight drums, each drum containing fruit of one treatment from one picking date for three removals of each of 36 fruit from each of the four orchards.

The storage atmospheres were:

(1) 16% oxygen plus 5% carbon dioxide
(2) 11% oxygen plus 10% carbon dioxide
(3) 5% oxygen without carbon dioxide
(4) Normal air storage.

Regular analyses were made during the storage period with an Orsat gas analysis apparatus and any necessary alterations made with cylinders of nitrogen and carbon dioxide. In the case of the 5% oxygen atmosphere, the carbon dioxide given off by the enclosed fruit was removed by chemical reaction with 14 lb of commercial grade flake sodium hydroxide placed in a container at the bottom of each drum.

After packing and sealing, the drums were stored at the C.O.D. Cool Stores, Thulimbah, at approximately 34°F.

Removals from storage were made on October 2, November 13, and December 12, 1956.

Immediately after the fruit for the first and second removals had been taken from each drum, the drum was resealed, and the atmosphere corrected by gases from cylinders. After removal from store the fruit was held at air temperatures for seven days, to simulate normal marketing delays, and was then inspected for storage disorders.

Results.—The results are summarized in Tables 1-7.

Table 1 shows that very little superficial scald was present when DPA dips were used and up to 5% carbon dioxide was present in the storage atmosphere. A concentration of 10 per cent. carbon dioxide in the storage atmosphere resulted in a greater amount of scald present even when DPA dips were

TABLE 1

SUPERFICIAL SCALD IN DPA TREATMENTS. 1956 EXPERIMENT

(Equivalent Mean Percentages)

Treatment*	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1	R2	R3	M3	M4	Mean
1000p.p.m.DPA ..	1·0	2·0	1·6	10·0	·1	3·0	7·8	7·1	·1	3·6
1000p.p.m.DPA+Wraps	·2	0	·1	1·4	0	·3	1·0	·8	0	·4
M3 (Picked Apr. 9) ..	1·0	2·0	1·6	11·3	·1	3·3	8·6			4·0
M4 (Picked Apr. 23) ..	·2	0	·1	0	0	0	·2			·1
R1 (Removed Oct. 1) ..	0	0	·2	0						0
R2 (Removed Nov. 13)	·3	·4	1·4	4·5						1·6
R3 (Removed Dec. 12) ..	1·5	2·6	1·0	12·5						4·4
Mean	·6	1·0	·9	5·7	0	1·6	4·4	4·0	·1	2·0

No analysis of variance was carried out because of the small amount of the disorder present.

TABLE 2

SUPERFICIAL SCALD WITH OILED PAPER WRAPS ONLY. 1956 EXPERIMENT

(Equivalent Mean Percentages)

Storage Treatment	R1*	R2	R3	M3	M4	Mean
Air Storage	0	6·4	1·0	4·7	·1	1·5
5%O_2	2·5	19·5	9·1	24·1	1·0	9·2
16%O_2 5%CO_2	22·5	69·1	74·5	90·6	16·6	55·4
11%O_2 10%CO_2	32·3	81·9	92·5	81·1	61·2	71·7
M3	26·4	63·3	58·9			49·2
M4	1·0	22·4	22·6			12·6
Mean	9·8	42·1	40·0	49·2	12·6	29·1

* R1, R2, R3, M3 and M4 as in Table 1.

R1 significantly less than R2 and R3 (1% level).

M4 significantly less than M3 (1% level) for all four atmospheres and the three removals.

Interaction of Atmospheres x Removals highly significant

For R1, Air Storage and 5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide and 11% oxygen plus 10% carbon dioxide (1% level).

For R2, Air Storage and 5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide and 11% oxygen plus 10% carbon dioxide (1% level).

For R3, Air Storage significantly less than 5% oxygen (5% level); 5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide (1% level); 16% oxygen plus 5% carbon dioxide significantly less than 11% oxygen plus 10% carbon dioxide (1% level). Loss of reactive power of NaOH in drums considered to be cause of higher scald in 5% oxygen than in normal atmosphere.

used. However, the use of oiled paper wrappers containing 15% mineral oil in addition to a DPA dip reduced the scald incidence to almost zero when the fruit was stored in this high carbon dioxide atmosphere. Because of the small amount of scald present in the experimental fruit treated with DPA, the effect of time of picking and length of the storage period on the storage behaviour of fruit treated with this compound could not be analysed statistically.

When oiled paper wraps alone were used (Table 2), considerable scald was present. Fruit from the first removal had less scald than that from either of the two later removals, and fruit from the second pick was less affected than fruit from the first pick.

The effect of storage atmosphere on scald incidence with oiled paper wraps was related to the length of the storage period and the carbon dioxide concentration (see footnote to Table 2). Both the increase in the incidence of the disorder with longer storage periods and the increase with high carbon dioxide concentrations in the storage atmosphere were highly significant.

There was a highly significant increase in mould with increase in the length of the storage period (Table 3). In addition, fruit from the first pick had significantly less mould than that from the second pick.

TABLE 3

MOULD IN 1956 EXPERIMENT

(Equivalent Mean Percentages)

Treatment*	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1	R2	R3	M3	M4	Mean
Wraps	7·3	2·1	1·0	1·5	1·1	2·5	4·7	1·6	3·8	2·6
1000p.p.m.DPA ..	9·9	2·8	4·2	4·9	1·8	5·2	10·3	3·3	7·4	5·2
1000p.p.m.DPA+Wraps	4·8	2·3	2·1	2·6	1·2	2·2	6·3	1·6	4·5	2·9
M3	4·5	1·7	1·4	1·5	1·0	1·6	4·3			2·1
M4	10·5	3·3	3·4	4·7	1·7	5·2	10·2			5·1
R1	2·0	·8	·9	1·8						1·3
R2	3·4	3·3	2·4	3·7						3·2
R3	22·0	3·7	4·0	3·2						6·9
Mean	7·2	2·4	2·3	2·8	1·3	3·2	6·9	2·1	5·1	3·5

* R1, R2, R3, M3 and M4 as in Table 1.

R1 significantly less than R2 (1% level).

R2 significantly less than R3 (1% level).

M3 significantly less than M4 (1% level).

Oiled paper wraps, 1000 p.p.m. DPA plus oiled paper wraps significantly less than 1000 p.p.m. DPA (1% level).

Interaction of Atmospheres x Removals highly significant.

For R1, no difference between atmospheres.

For R2, no difference between atmospheres.

For R3, 5% oxygen ; 16% oxygen plus 5% carbon dioxide ; 11% oxygen plus 10% carbon dioxide significantly less than Air Storage (1% level).

Very little soggy breakdown was encountered in the experiment irrespective of whether the fruit was wrapped, unwrapped or treated with DPA (Table 4). However, in fruit stored under normal atmospheres there was a definite increase of the disorder with increase in the length of the storage period and, in addition, fruit from the first pick had more soggy breakdown than fruit from the second pick. Because of the small amount of the disorder present an analysis of variance was not carried out.

TABLE 4

SOGGY BREAKDOWN IN 1956 EXPERIMENT

(Equivalent Mean Percentages)

Treatment*	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1	R2	R3	M3	M4	Mean
Wraps	9·5	1·6	·5	1·2	·2	1·5	7·9	3·6	2·7	3·2
1000p.p.m.DPA ..	3·9	·6	·5	2·6	·1	1·6	3·9	2·3	1·5	1·9
1000p.p.m.DPA+Wraps	6·1	2·8	·1	2·3	·2	1·9	6·3	2·2	3·5	2·8
M3	8·6	1·2	·4	·6	·1	1·2	6·7			2·7
M4	4·4	2·2	·3	3·4	·3	2·1	5·3			2·6
R1	·6	·1	0	·1						·2
R2	3·9	1·0	·1	1·5						1·6
R3	15·0	3·8	·9	4·4						6·0
Mean	6·5	1·7	·3	2·0	·2	1·6	6·0	2·7	2·6	2·6

* R1, R2, R3, M3 and M4 as in Table 1.

No analysis of variance was carried out because of the small amount of the disorder present.

Analyses of total wastage, which included wastage from mould, soggy breakdown and superficial scald, showed that there was a significant increase in wastage with increase in the length of the storage period, and that the effect of storage atmosphere was highly significant (Tables 5 and 6).

The firmness of the fruit was significantly affected by the length of the storage period (Table 7), inasmuch as fruit from the first removal was firmer than that from the second and third removals. Fruit from the first pick was not as firm as that from the second pick. Air-stored fruit was not as firm as fruit stored in an atmosphere of 5% oxygen, which in turn was not as firm as that stored in the 16% oxygen plus 5% carbon dioxide or the 11% oxygen plus 10% carbon dioxide atmospheres.

There is some evidence from the results that DPA dips had an effect on the firmness of the fruit. Under an atmosphere of 5% oxygen, fruit in oiled paper wraps was significantly softer than that treated with DPA irrespective of whether the treated fruit was wrapped or not. There were also some effects on firmness due to DPA dips when fruit was stored under atmospheres of either 5% oxygen or 16% oxygen plus 5% carbon dioxide.

TABLE 5

TOTAL BREAKDOWN WITH OILED PAPER WRAPS ONLY. 1956 EXPERIMENT

(Equivalent Mean Percentages)

Storage Treatment	R1*	R2	R3	M3	M4	Mean
Air Storage	2·3	15·4	56·5	24·7	16·5	20·4
5%O_2	4·4	29·2	20·7	30·7	6·1	16·5
16%O_2 5%CO_2	25·4	74·0	80·7	93·0	21·6	60·7
11%C_2 10%CO_2	39·9	85·6	97·0	85·6	70·3	78·4
M3	30·1	70·1	81·1			61·2
M4	4·3	32·2	51·1			26·1
Means	14·7	51·2	67·0	61·2	26·1	43·2

* R1, R2, R3, M3 and M4 as in Table 1.

M4 significantly less than M3 (1% level).

Interactions of Atmospheres x Removals and Atmospheres x Maturities are highly significant.

For R1 and R2, Air Storage and 5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide and 11% oxygen plus 10% carbon dioxide (1% level).

For R3, 5% oxygen significantly less than Air Storage (1% level) ; Air Storage significantly less than 16% oxygen plus 5% carbon dioxide (1% level) ; 16% oxygen plus 5% carbon dioxide significantly less than 11% oxygen plus 10% carbon dioxide (1% level).

For Air Storage, no difference in maturities.

For 5% oxygen and 16% oxygen plus 5% carbon dioxide ; M4 significantly less than M3 (1% level) ; R1 significantly less than R2 and R3 (1% level).

For 11% oxygen and 10% carbon dioxide, M4 significantly less than M3 (5% level) ; R1 significantly less than R2 (1% level) ; R2 significantly less than R3 (5% level).

TABLE 6

TOTAL BREAKDOWN IN DPA TREATMENTS. 1956 EXPERIMENT
(Equivalent Mean Percentages)

Treatment*	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1	R2	R3	M3	M4	Mean
1,000 p.p.m. DPA	14·1	5·1	7·2	16·1	2·4	9·7	23·0	11·9	8·5	10·1
1,000 p.p.m. DPA + Wraps ..	10·6	4·3	3·0	6·0	1·3	4·7	14·4	4·5	6·9	5·7
M3	11·0	4·5	5·0	12·2	1·9	6·5	19·2			7·8
M4	13·7	4·8	4·7	9·0	1·7	7·5	17·7			7·7
R1	2·7	1·0	2·2	1·4						1·8
R2	7·0	3·9	5·5	12·7						7·0
R3	35·5	12·0	7·5	23·4						18·5
Mean	12·3	4·7	4·8	10·5	1·8	7·0	18·5	7·8	7·7	7·7

* R1, R2, R3, M3 and M4 as in Table 1.

DPA dips + oiled paper wraps significantly less than DPA dips (1% level).

R1 significantly less than R2 (1% level).

R2 significantly less than R3 (1% level).

5% oxygen and 16% oxygen plus 5% carbon dioxide significantly less than 11% oxygen plus 10% carbon dioxide and Air Storage (1% level).

Interactions of Treatments x Maturities and Atmospheres x Removals are significant.

For M3, DPA dips + oiled paper wraps significantly less than DPA dips (1% level).

For M4, no difference in Treatments.

For R1, no difference in Atmospheres.

For R2, 5% oxygen significantly less than 11% oxygen plus 10% carbon dioxide (1% level) ; 16% oxygen plus 5% carbon dioxide significantly less than 11% oxygen plus 10% carbon dioxide (1% level).

For R3, 16% oxygen plus 5% carbon dioxide and 5% oxygen significantly less than 11% oxygen plus 10% carbon dioxide (1% level) ; 11% oxygen plus 10% carbon dioxide significantly less than Air Storage (5% level).

TABLE 7

FIRMNESS (LB) OF FRUIT IN 1956 EXPERIMENT

Treatment	Air Storage	5%O_2	16%O_2 5%CO_2	11%O_2 10%CO_2	R1*	R2	R3	M3	M4	Mean
Wraps	11·06	12·25	13·33	13·81	11·88	13·20	12·77	12·48	12·75	12·61
1,000 p.p.m. DPA	10·75	12·81	13·58	13·48	12·06	12·89	13·02	12·47	12·84	12·66
1,000 p.p.m. DPA + Wraps	10·96	12·81	13·67	13·23	12·03	12·95	13·02	12·54	12·79	12·67
M3	10·72	12·46	13·42	13·39	11·91	12·76	12·82			12·50
M4	11·12	12·79	13·64	13·62	12·07	13·27	13·04			12·80
R1	10·54	12·10	12·67	12·65						11·99
R2	11·31	12·88	13·94	13·94						13·02
R3	10·92	12·90	13·98	13·94						12·93
Mean	10·92	12·62	13·53	13·51	11·99	13·02	12·93	12·50	12·80	12·65

*R1, R2, R3, M3 and M4 as in Table 1.

R1 significantly less than R2 and R3 (1% level).

M3 significantly less than M4 (1% level).

Air Storage significantly less than 5% Oxygen (1% level).

5% oxygen significantly less than 16% oxygen plus 5% carbon dioxide and 11% oxygen plus 10% carbon dioxide (1% level).

For Removals and Maturities, no difference between treatments.

Interaction of Treatments × Atmospheres is significant.

For Air Storage and 16% oxygen plus 5% carbon dioxide, no difference between treatments.

For 5% oxygen, Oiled paper wraps significantly less than DPA dips and DPA dips plus oiled paper wraps (5% level).

For 11% oxygen plus 10% carbon dioxide, DPA dips plus oiled paper wraps significantly less than oiled paper wraps (5% level).

III. 1957 EXPERIMENT

Objective.—To assess the effect of various anti-oxidants, both cytochrome and polyphenol oxidase inhibitors, on the incidence of superficial scald.

TABLE 8

SUPERFICIAL SCALD. 1957 EXPERIMENT

Treatment	Replicate 1 (%)	Replicate 2 (%)	Replicate 3 (%)	Mean (%)
1. Untreated control (sulphite paper wraps)	94·0	96·0	98·0	96·0
2. Oiled paper wraps (15 % mineral oil)	8·0	0	58·0	22·0
3. 1·8 mg DPA impregnated paper wraps (1·8 mg DPA/10 in. square)	4·0	0	0	1·3
4. 3·6 mg DPA impregnated paper wraps (3·6 mg DPA/10 in. square)	0	0	0	0
5. 1,000 p.p.m. DPA dip plus oiled paper wraps (15% mineral oil)	0	0	4·0	1·3
6. 500 p.p.m. DPA dip plus oiled paper wraps (15% mineral oil)	4·0	0	0	1·3
7. 1,000 p.p.m. DPA dip	0	0	2·0	0·7
8. 5,000 p.p.m. DPA dip	2·0	0	0	0·7
9. 2,000 p.p.m. diphenyloxide dip	86·0	76·0	84·0	82·0
10. 500 p.p.m. diphenyloxide dip	98·0	90·0	96·0	94·7
11. 2,000 p.p.m. thiourea dip	98·0	90·0	82·0	90·0
12. 500 p.p.m. thiourea dip	74·0	94·0	88·0	85·3
13. 2,000 p.p.m. salicylic acid dip	90·0	94·0	94·0	92·7
14. 500 p.p.m. salicylic acid dip	10·0	100·0	78·0	62·7
15. 2,000 p.p.m. p hydroxydiphenyl dip	30·0	66·0	66·0	54·0
16. 500 p.p.m. p hydroxydiphenyl dip	86·0	88·0	100·0	91·3
17. 2,000 p.p.m. sodium azide dip	6·0	98·0	92·0	65·3
18. 500 p.p.m. sodium azide dip	56·0	94·0	66·0	72·0
19. 2,000 p.p.m. sodium diethyldithiocarbamate dip	64·0	92·0	96·0	84·0
20. 500 p.p.m. sodium diethyldithiocarbamate dip	90·0	92·0	100·0	94·0
21. 2,000 p.p.m. diaminoethanetetraacetic acid—disodium salt dip	100·0	96·0	98·0	98·0
22. 500 p.p.m. diaminoethanetetraacetic acid—disodium salt dip	92·0	88·0	96·0	92·0
23. 2,000 p.p.m. L cysteine hydrochloride dip	90·0	96·0	100·0	95·3
24. 500 p.p.m. L cysteine hydrochloride dip	84·0	90·0	96·0	90·0
25. 2,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	2·0	0	0	0·7
26. 500 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	0	0	0
27. 2,000 p.p.m. diphenylthiocarbazone dip	30·0*	50·0*	92·0*	57·3
28. 500 p.p.m. diphenylthiocarbazone dip	72·0	36·0*	84·0	64·0
29. 2,000 p.p.m. 2 thiouracil dip	96·0	100·0	64·0	86·7
30. 500 p.p.m. 2 thiouracil dip	96·0	72·0	40·0	69·3
31. 2,000 p.p.m. phenylthiourea dip	88·0	96·0	94·0	92·7
32. 500 p.p.m. phenylthiourea dip	80·0	82·0	66·0	76·0
33. 2,000 p.p.m. cobalt sulphate dip	94·0	88·0	98·0	93·3
34. 500 p.p.m. cobalt sulphate dip	46·0	64·0	62·0	57·3
35. 500 p.p.m. diphenylbenzidene dip	90·0	100·0	90·0	93·3
36. 95% ethyl alcohol dip	98·0	92·0	86·0	92·0

* Injury to fruit present.

Fruit.—Fruit for the experiment was obtained from one orchard and was 2½ in. in diameter. The fruit was picked in March to ensure that it would be susceptible to superficial scald during the storage period.

Pre-storage Treatments.—Thirty-six different treatments were used in the experiment. They are given in Table 8. Wherever possible, aqueous solution dips were used, but with non-water-soluble substances ethyl alcohol was used as the solvent. Each treatment consisted of 150 fruit. After dipping the fruit was drained and allowed to dry.

Storage and Post-storage.—The 150 dipped fruit in each treatment were divided into three replicates each containing 50 fruit, and replicates for six treatments were packed into each of eighteen 44 gal drums in a randomized manner to obviate drum effects. After packing, the drums were sealed and stored in the Hamilton Cool Stores, Brisbane, at 34°F. The atmospheres within the drums were maintained at 16% oxygen plus 5% carbon dioxide to encourage development of superficial scald. The drums were sealed on April 16, and removed from the storage chamber and opened on November 11, 1957. The fruit was held at atmospheric temperatures for seven days, to simulate normal marketing delays, and then inspected for the incidence of superficial scald.

Results.—Of the 36 treatments used in the experiment, only nine had any marked effect on the incidence of the disorder (Table 8). Six were diphenylamine applied either as a dip or incorporated in paper wraps, and two involved the use of 6 ethoxy 12 dihydro 224 trimethylquinoline in dip form. Oiled paper wraps, while not so effective as diphenylamine or 6 ethoxy 12 dihydro 224 trimethylquinoline, yielded good results.

Some of the remaining compounds used in the experiment gave good control in one of the replicates but not in the other two. An inspection of the arrangement of the treatments in the experimental containers revealed that where this occurred the replicate was adjacent to either a diphenylamine or a 6 ethoxy 12 dihydro 224 trimethylquinoline treatment and a proximity effect was thus involved.

IV. 1958 EXPERIMENTS

(a) Experiment 1

Objective.—To assess the effect of a number of compounds, including some structurally similar to DPA, on superficial scald.

Fruit.—Fruit was obtained from one orchard and was of 2½ in. diameter. It was picked in late March to ensure susceptibility to superficial scald during the storage period.

Pre-storage Treatments.—The 36 treatments used are listed in Table 9. They were applied as ethyl alcohol solutions. Each treatment consisted of 150 fruit. After treatment the fruit was drained and allowed to dry.

Storage and Post-storage.—The dipped fruit was divided into three replicates of 50 fruit and replicates for six treatments were packed into each of eighteen

44 gal drums. To obviate drum effects, the replicates were randomized in the drums. After packing, the drums were sealed and stored in the Hamilton Cool Stores, Brisbane, at 34°F. The atmospheres inside the drums were maintained at 16% oxygen plus 5% carbon dioxide to encourage the development of scald. Removal of the drums from the storage chamber was made on October 29, 1958. The drums were then opened and the fruit held at atmospheric temperatures for seven days. An inspection was then made and the amount of superficial scald recorded.

TABLE 9

SUPERFICIAL SCALD. EXPERIMENT 1, 1958

Treatment	Replicate 1 (%)	Replicate 2 (%)	Replicate 3 (%)	Mean (%)
1. Oiled paper wraps (15% mineral oil)	48·0	32·0	56·0	45·3
2. Untreated control (sulphite paper wraps)	86·0	52·0	96·0	78·0
3. DPA impregnated paper wraps (3·6 mg/10 in. square)	2·0	2·0	0	1·3
4. DPA impregnated paper wraps (1·8 mg/10 in. square)	6·0	0	0	2·0
5. 1,000 p.p.m. DPA dip plus oiled paper wraps (15% mineral oil)	0	0	0	0
6. 500 p.p.m. DPA dip plus oiled paper wraps (15% mineral oil)	0	0	2·0	0·7
7. 1,000 p.p.m. DPA dip	2·0	0	0	0·7
8. 500 p.p.m. DPA dip	14·0	8·0	8·0	10·0
9. 2,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	0	0	0
10. 1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	2·0	8·0	3·3
11. 2,000 p.p.m. phenothiazine dip	86·0	60·0	72·0	72·7
12. 1,000 p.p.m. phenothiazine dip	76·0	90·0	88·0	84·7
13. 2,000 p.p.m. adenine dip	100·0	88·0	100·0	96·0
14. 1,000 p.p.m. adenine dip	42·0	98·0	88·0	76·0
15. 2,000 p.p.m. pyrrole dip	96·0	96·0	92·0	94·7
16. 1,000 p.p.m. pyrrole dip	94·0	92·0	86·0	90·7
17. 2,000 p.p.m. piperidine dip	48·0	90·0	92·0	76·7
18. 1,000 p.p.m. piperidine dip	96·0	92·0	88·0	92·0
19. 2,000 p.p.m. pyrrolidine dip	34·0	92·0	90·0	72·0
20. 1,000 p.p.m. pyrrolidine dip	90·0	92·0	88·0	90·0
21. 2,000 p.p.m. carbamilide dip	92·0	100·0	98·0	96·7
22. 1,000 p.p.m. carbamilide dip	90·0	98·0	100·0	96·0
23. 2,000 p.p.m. carbazole dip	90·0	80·0	92·0	87·3
24. 1,000 p.p.m. carbazole dip	98·0	88·0	96·0	94·0
25. 2,000 p.p.m. p phenylenediamine dip	94·0	78·0	96·0	89·3
26. 1,000 p.p.m. p phenylenediamine dip	98·0	78·0	94·0	90·0
27. 2,000 p.p.m. diphenylguanidine dip	92·0	96·0	98·0	95·3
28. 1,000 p.p.m. diphenylguanidine dip	98·0	92·0	96·0	95·3
29. 2,000 p.p.m. 24 dinitrophenylhydrazine dip	94·0	100·0	92·0	95·3
30. 1,000 p.p.m. 24 dinitrophenylhydrazine dip	94·0	96·0	70·0	86·7
31. 2,000 p.p.m. methyl p aminophenol dip	82·0	90·0	80·0	84·0
32. 1,000 p.p.m. methyl p aminophenol dip	86·0	98·0	94·0	92·7
33. 2,000 p.p.m. hexamine dip	90·0	100·0	98·0	96·0
34. 1,000 p.p.m. hexamine dip	100·0	92·0	92·0	94·7
35. 2,000 p.p.m. phenacetin dip	96·0	100·0	94·0	96·7
36. 1,000 p.p.m. phenacetin dip	56·0	96·0	92·0	81·3

Results.—The results are summarized in Table 9. Only nine treatments had any marked effect on the incidence of superficial scald. Six involved the use of diphenylamine either as a dip or incorporated in paper wraps, two were dips of 6 ethoxy 12 dihydro 224 trimethylquinoline and one was the standard oiled paper wraps. None of the other materials were of any use in controlling scald despite their similarity in structure to diphenylamine. As in the 1957 experiment, some apparent control was observed in one or more of the replicates of the ineffective treatments. This effect was once more shown to be due to experimental fruit being adjacent to either a diphenylamine or a 6 ethoxy 12 dihydro 224 trimethylquinoline replicate.

(b) Experiment 2

Objective.—To determine the amount of control of superficial scald effected by diphenylamine dips over a more extended picking period than that used in earlier experiments.

Fruit.—The fruit was obtained from six orchards and the picking dates were March 20, March 27, April 3, April 10, April 17, and April 24.

Pre-storage treatments.—The following pre-storage treatments were used in the investigations:—

(1) Untreated control.

(2) 1000 p.p.m. diphenylamine dip.

(3) Untreated fruit in 0·015 gauge polyethylene case liners.

(4) 1000 p.p.m. diphenylamine dip with fruit in 0·015 gauge polyethylene case liners.

One half-bushel case was taken from each orchard at each picking date for each treatment, making a total of 144 half-bushel cases. Polyethylene case liners were used to create modified controlled atmospheres with carbon dioxide contents in excess of that normally found in the atmosphere so that the effect of high concentrations of this gas could be studied over a range of picking dates.

Storage and Post-storage.—After treatment, the fruit was cool-stored in the Hamilton Cool Stores, Brisbane, at 34°F within 48 hr of harvest date. Removals from store were made seven months later. After removal from store the fruit was held for seven days at atmospheric temperatures and then inspected for superficial scald incidence.

Results.—The results are summarized in Table 10. No scald was present in DPA-treated fruit irrespective of the time of picking and the atmosphere

under which the fruit was stored. There was no decrease in scald incidence, in the untreated controls, with increase in maturity. In the untreated fruit there was no evidence that polyethylene liners increased scald incidence.

TABLE 10

SUPERFICIAL SCALD. EXPERIMENT 2, 1958

Picking Date	Treatment			
	A (%)	B (%)	C (%)	D (%)
March 20	97·7	0	98·5	0
March 27	98·7	0	99·4	0
April 3	92·7	0	96·5	0
April 10	95·4	0	97·0	0
April 17	86·7	0	96·1	0
April, 24	93·8	0	96·6	0

V. 1959 EXPERIMENTS

(a) Experiment 1

Objective.—To assess the effect of a number of treatments on superficial scald.

Fruit.—The fruit was obtained from one orchard and was of 2½ in. diameter. It was picked late in March to ensure susceptibility to superficial scald during the storage period.

Pre-storage treatments.—The treatments used are shown in Table 11. They were applied as alcoholic solutions or, where solution could not be effected, fine suspensions in ethenol. Each treatment consisted of 150 fruit.

Storage and Post-storage.—The treated fruit was divided into three replicates of 50 fruit and replicates for six treatments were packed into one of eighteen 44 gal drums. To obviate drum effects the replicates were randomized in the drums. After packing, the drums were sealed and stored in the Hamilton Cool Stores, Brisbane, at 34°F. The atmospheres within the drums maintained at 16% oxygen plus 5% carbon dioxide. Removal of the drums from the storage chamber was made on October 26, 1959. The drums were then opened and the fruit held under normal atmospheric conditions for seven days. An inspection was then made and the amount of superficial scald recorded.

Results.—The results are summarized in Table 11. Of the 36 treatments, 12 gave marked control of superficial scald. Four of these involved diphenylamine or 6 ethoxy 12 dihydro 224 trimethylquinoline. Other treatments

which gave good control were NN′ diphenyl p phenylenediamine, p hydroxydiphenylamine, and diphenylcarbamylchoride. N phenyl 1 napthylamine gave good control at 1000 p.p.m. concentrations but at the higher concentration (5000 p.p.m.) was not so effective. Both 1, 2, 3, 4 tetrahydroisoquinoline and p amino diphenylamine appeared to give slight control at the concentrations used and are worthy of further investigations.

TABLE 11

SUPERFICIAL SCALD. EXPERIMENT 1, 1959

Treatment	Replicate 1 (%)	Replicate 2 (%)	Replicate 3 (%)	Mean (%)
1. Untreated control—sulphite paper wraps	100·0	100·0	100·0	100·0
2. Oiled paper wraps (15% mineral oil)	96·0	90·0	100·0	95·3
3. 1,000 p.p.m. diphenylamine dip	0	0	0	0
4. 5,000 p.p.m. diphenylamine dip	0	0	0	0
5. 1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	0	0	0
6. 5,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	6·0	10·0	5·3
7. 1,000 p.p.m. p aminobenzoic acid dip	100·0	100·0	100·0	100·0
8. 5,000 p.p.m. p aminobenzoic acid dip	92·0	100·0	94·0	95·3
9. 1,000 p.p.m. p phenylenediamine dip	100·0	100·0	100·0	100·0
10. 5,000 p.p.m. p phenylenediamine dip	100·0	100·0	100·0	100·0
11. 1,000 p.p.m. acridone dip*	100·0	100·0	100·0	100·0
12. 5,000 p.p.m. acridone dip*	100·0	100·0	100·0	100·0
13. 1,000 p.p.m. 1,234 tetrahydroisoquinoline dip	80·0	80·0	96·0	85·3
14. 5,000 p.p.m. 1,234 tetrahydroisoquinoline dip	96·0	100·0	96·0	97·3
15. 1,000 p.p.m. theophylline dip	100·0	100·0	100·0	100·0
16. 5,000 p.p.m. theophylline dip	100·0	100·0	100·0	100·0
17. 1,000 p.p.m. NN′ diphenyl p phenylenediamine dip*	0	12·0	10·0	7·3
18. 5,000 p.p.m. NN′ diphenyl p phenylenediamine dip*	6·0	4·0	6·0	5·3
19. 1,000 p.p.m. N phenyl 1 naphthylamine dip	0	14·0	0	4·7
20. 5,000 p.p.m. N phenyl 1 naphthylamine dip	52·0	52·0	100·0	68·0
21. 1,000 p.p.m. p hydroxydiphenylamine dip	0	0	0	0
22. 5,000 p.p.m. p hydroxydiphenylamine dip	0	0	0	0
23. 1,000 p.p.m. p amino diphenylamine dip†	70·0	84·0	90·0	74·7
24. 5,000 p.p.m. p amino diphenylamine dip†	100·0	94·0	100·0	98·0
25. 1,000 p.p.m. acridine dip	100·0	100·0	100·0	100·0
26. 5,000 p.p.m. acridine dip	100·0	100·0	100·0	100·0
27. 1,000 p.p.m. piperazine dip	100·0	100·0	100·0	100·0
28. 5,000 p.p.m. piperazine dip	100·0	100·0	100·0	100·0
29. 1,000 p.p.m. sym diethyldiphenylurea dip	100·0	92·0	100·0	97·3
30. 5,000 p.p.m. sym diethyldiphenylurea dip	100·0	100·0	100·0	100·0
31. 1,000 p.p.m. diphenylcarbamylchloride dip	0	0	0	0
32. 5,000 p.p.m. diphenylcarbamylchloride dip	0	0	10·0	3·3
33. 1,000 p.p.m. diphenylsuccinate dip	100·0	100·0	100·0	100·0
34. 5,000 p.p.m. diphenylsuccinate dip	100·0	100·0	100·0	100·0
35. 1,000 p.p.m. N (naphthyl) ethylenediamine dip	100·0	100·0	100·0	100·0
36. 5,000 p.p.m. N (naphthyl) ethylenediamine dip	98·0	100·0	100·0	99·3

* Residue on fruit.

† Skin damage to fruit.

(b) Experiment 2

Objective.—To assess the effect of diphenylamine on scald incidence over a range of early picking dates.

Fruit.—Fruit was obtained from four orchards. The picking dates were February 23, March 9, March 23, and April 6, 1959.

Pre-storage Treatment.—Three treatments were used in the investigation:—

(1) Control—oiled paper wraps containing 15% mineral oil and stored under normal atmospheric cool storage conditions.

(2) Diphenylamine wraps containing 1·8 mg DPA/10 in. square and stored under normal atmospheric cool storage conditions.

(3) Diphenylamine wraps containing 1·8 mg DPA/10 in. square and stored under controlled atmospheres of 16% oxygen plus 5% carbon dioxide.

Four half-bushel cases of fruit were harvested from each orchard at each of the four picking dates for each of the three treatments. Removals of the experimental fruit from store were made at the end of September and the end of October, 1959. After removal, the fruit was held for seven days at atmospheric temperatures and then inspected for superficial scald incidence.

Results.—The results are summarized in Tables 12 and 13.

TABLE 12

SUPERFICIAL SCALD. EXPERIMENT 2, 1959

Treatment	First Removal*				Second Removal			
	M1 (%)	M2 (%)	M3 (%)	M4 (%)	M1 (%)	M2 (%)	M3 (%)	M4 (%)
Oiled paper wraps—air storage	72·9	74·9	46·3	15·2	63·3	69·3	47·9	15·9
DPA wraps 1·5 mg/10 in. square—air storage ..	2·6	2·2	2·5	0·4	2·9	3·8	7·5	1·9
DPA wraps 1·5 mg/10 in. square—16% O_2 plus 5% CO_2	13·5	14·1	6·4	1·3	7·0	9·5	2·1	0·9

* Picking dates—M1, Feb. 23 ; M2, Mar.9 ; M3, Mar. 23 ; M4, Apr. 6.

TABLE 13

INTERNAL BREAKDOWN. EXPERIMENT 2, 1959

Treatment	Second Removal*			
	M1 (%)	M2 (%)	M3 (%)	M4 (%)
Oiled pape· wraps—air storage	90·0	82·5	78·7	82·5
DPA wraps 1·5 mg/10 in. square—air storage ..	80·0	66·3	77·5	51·3
DPA wraps 1·5 mg/10 in. square—16% O_2 plus 5% CO_2	56·3	20·0	38·8	6·3

* Picking dates as in Table 12.

The diphenylamine-treated wraps considerably reduced the incidence of superficial scald in fruit stored under normal atmospheres and in a controlled atmosphere of 16% oxygen plus 5% carbon dioxide. The increase in maturity of fruit stored in oiled paper wraps resulted in a decrease in the amount of the disorder present. There is a trend which suggests that fruit treated with diphenylamine wraps and held under an atmosphere containing a high carbon dioxide concentration was more susceptible to the disorder than fruit held under normal atmospheres, particularly in the early maturities.

Ten fruit from each case of the second removal were cut and the amount of internal breakdown recorded. Table 13 summarizes the results. Internal breakdown was very prevalent in both the control and the air-stored fruit treated with diphenylamine wraps. When the fruit was stored in an atmosphere of 16% oxygen plus 5% carbon dioxide the incidence of this disorder was considerably reduced. In addition, there appears to be a trend to a reduction in breakdown with increase in maturity in the fruit stored under the controlled atmosphere. Diphenylamine appears to have caused a reduction in internal breakdown in the fruit stored at normal atmospheres. A similar reduction has been reported by Padfield (1959).

(c) Experiment 3

Objective.—To assess the effect on superficial scald of very low concentrations of diphenylamine used alone and in conjunction with oiled paper wraps.

Fruit.—The fruit was obtained from three orchards and was picked on April 1, 1959.

TABLE 14

SUPERFICIAL SCALD. EXPERIMENT 3. 1959

Treatment	Superficial Scald (%)
Control (sulphite paper wraps)	92·5
Oiled paper wraps (15% mineral oil)	3·8
50 p.p.m. diphenylamine dip	46·9
100 p.p.m. diphenylamine dip	74·7
200 p.p.m. diphenylamine dip	24·2
400 p.p.m. diphenylamine dip	16·3
800 p.p.m. diphenylamine dip	2·5
50 p.p.m. diphenylamine dip plus oiled paper wraps ..	3·0
100 p.p.m. diphenylamine dip plus oiled paper wraps ..	4·8
200 p.p.m. diphenylamine dip plus oiled paper wraps ..	0
400 p.p.m. diphenylamine dip plus oiled paper wraps ..	0
800 p.p.m. diphenylamine dip plus oiled paper wraps ..	0

Pre-storage Treatments.—The treatments used are shown in Table 14.

Storage and Post-storage.—After treatment, the fruit was stored in the Hamilton Cool Stores, Brisbane at 34°F. Removal from the storage chamber was made on November 2, 1959, and after holding for seven days at atmospheric temperatures the fruit was inspected for superficial scald incidence.

Results.—Table 14 summarizes the results. Scald incidence was very high in the control lots but was very well controlled by oiled paper wraps containing 15% mineral oil. There was a gradual decrease in the incidence of the disorder with increase in the diphenylamine content of the dips used. A dip of 800 p.p.m. gave slightly better control than the oiled paper wraps. When a diphenylamine dip was used in conjunction with oiled paper wraps, complete control of scald was effected where the diphenylamine content of the dip was 200 p.p.m. or greater.

VI. 1960 EXPERIMENTS

(a) Experiment 1

Objective.—To retest compounds that had given some control of superficial scald in previous experiments.

Fruit.—Fruit was obtained from one orchard and was of 2½ in. diameter. It was harvested during the first week of April to ensure susceptibility to superficial scald.

Pre-storage treatments.—The 16 treatments used are shown in Table 15. Each treatment was applied as an alcoholic solution and consisted of 75 fruit divided into three replicates each of 25. Replicates for 16 treatments were one of three 44 gal drums, and to obviate drum effects the replicates were randomized in the drums.

TABLE 15

SUPERFICIAL SCALD. EXPERIMENT 1, 1960

Treatment	Replicate 1 (%)	Replicate 2 (%)	Replicate 3 (%)	Mean (%)
1. 5,000 p.p.m. diphenylamine dip	0	0	0	0
2. 1,000 p.p.m. diphenylamine dip	0	0	0	0
3. 5,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0	0	0	0
4. 1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	10·0	0	0	3·3
5. 5,000 p.p.m. p. hydroxydiphenylamine dip	0	0	0	0
6. 1,000 p.p.m. p hydroxydiphenylamine dip	36·9	35·0	45·0	39·0
7. 5,000 p.p.m. diphenylcarbamylchloride dip	0	0	0	0
8. 1,000 p.p.m. diphenylcarbamylchloride dip	25·0	25·0	20·0	23·3
9. 5,000 p.p.m. N phenyl 1 naphthylamine dip	15·0	0	0	5·0
10. 1,000 p.p.m. N phenyl 1 naphthylamine dip	80·0	50·0	45·0	58·3
11. 5,000 p.p.m. sym dimethyldiphenylurea dip	100·0	100·0	100·0	100·0
12. 1,000 p.p.m. sym dimethyldiphenylurea dip	100·0	95·0	100·0	98·3
13. 5,000 p.p.m. NN′ diphenyl p phenylenediamine dip ..	5·0	0	0	1·7
14. 1,000 p.p.m. NN′ diphenyl p phenylenediamine dip ..	20·0	25·0	35·0	26·7
15. 5,000 p.p.m. nordihydroguairetic acid dip	100·0	100·0	90·0	96·7
16. 1,000 p.p.m. nordihydroguairetic acid dip	100·0	100·0	100·0	100·0

Storage and Post-storage.—After packing, the drums were sealed and stored in the Hamilton Cool Stores, Brisbane, at 34°F. The atmospheres within the drums were maintained at 16% oxygen plus 5% carbon dioxide. The drums

were removed from the storage chamber on October 27, 1960, opened, and held at atmospheric temperatures for seven days. An inspection of the fruit was then carried out and the incidence of superficial scald recorded.

Results.—The results are summarized in Table 15. Of the 16 treatments used, only four failed to effect any control of superficial scald. The 12 successful treatments were those that yielded good control in the 1959 experiment. Both diphenylamine and 6 ethoxy 12 dihydro 224 trimethylquinoline gave good control irrespective of concentrations, but p hydroxydiphenylamine, diphenylcarbamyl-chloride, N phenyl 1 napthylamine and NN′ diphenyl p phenylenediamine were more effective at the 5000 p.p.m. level.

(b) Experiment 2

Objective.—To compare 6 ethoxy 12 dihydro 224 trimethylquinoline with diphenylamine and oiled paper wraps for superficial scald control.

Fruit.—The fruit was obtained from one orchard and was picked during the first week in April.

Pre-storage treatments.—The treatments used in the experiment were—

(1) Oiled paper wraps containing 15% mineral oil.
(2) 1000 p.p.m. diphenylamine dip.
(3) 500 p.p.m. diphenylamine dip.
(4) 1000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip.
(5) 500 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip.

Four replicates of each treatment were used.

Storage and Post-storage.—After packing, the fruit was stored in the Hamilton Cool Stores, Brisbane, at 34°F. It was removed from the storage chamber on October 27, 1960, held for seven days at atmospheric temperatures and then inspected for superficial scald.

Results.—The results are summarized in Table 16. No scald was present in any fruit treated with either diphenylamine or 6 ethoxy 12 dihydro 224 trimethylquinoline, while the fruit wrapped in oiled paper wraps was moderately affected by the disorder.

TABLE 16

SUPERFICIAL SCALD. EXPERIMENT 2, 1960

Treatment	Superficial Scald (%)
1. Oiled paper wraps	13·7
2. 1,000 p.p.m. diphenylamine dip	0
3. 500 p.p.m. diphenylamine dip	0
4. 1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0
5. 500 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip	0

(c) Experiment 3

Objective.—To determine at what stage after picking diphenylamine and 6 ethoxy 12 dihydro 224 trimethylquinoline should be used for superficial scald control.

Fruit.—Eleven half-bushel cases of fruit were obtained from one orchard. The fruit was picked during the first week in April to ensure scald susceptibility.

Pre-storage Treatment.—After picking, the fruit was packed into cases and two cases were treated prior to storage with 1000 p.p.m. diphenylamine and 1000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dips respectively.

Storage and Post-storage.—All cases were stored in the Hamilton Cool Stores, Brisbane. Two of the naked cases were removed from store at intervals of 6 weeks, treated with the test compounds and then returned to the storage chamber. One case remained untreated throughout the storage period. The fruit was removed from the storage chamber on October 27, 1960, held for seven days at atmospheric temperatures and then inspected for scald incidence.

Results.—The results are summarized in Table 17. There was a gradual increase in the incidence of superficial scald with delay in application of either diphenylamine or 6 ethoxy 12 dihydro 224 trimethylquinoline.

TABLE 17

SUPERFICIAL SCALD. EXPERIMENT 3, 1960

Time of Application (weeks after storage)	1,000 p.p.m. diphenylamine dip (%)	1,000 p.p.m. 6 ethoxy 12 dihydro 224 trimethylquinoline dip (%)
0	0	1·4
6	5·6	1·4
12	20·5	30·0
18	36·1	58·3
24	56·4	77·8
Untreated Control	63·3	

VII. DISCUSSION

From the results obtained in the experiments, it is clear that the development of superficial scald in stored Granny Smith apples may be controlled by treatment prior to storage with DPA either as a pre-storage dip or incorporated in paper wraps.

The concentration of DPA required depends on the storage atmosphere and the maturity of the fruit at picking.

Dipping in DPA 1000 p.p.m. is better than wrapping in oiled paper wraps and gives almost complete control of superficial scald in air storage and in

controlled atmospheres containing up to 5% carbon dioxide. At 10% carbon dioxide level, oiled paper wraps were necessary in addition to the DPA dip. For air storage, dips containing less than 800 p.p.m. DPA are not as effective as oiled paper wraps in controlling superficial scald, but a dip of 200 p.p.m. DPA, together with oiled paper wraps, gives complete control.

Wraps impregnated with DPA give a good measure of control of superficial scald. The concentrations used were 1·8 mg DPA per 10 in. square and 3·6 mg DPA per 10 in. square. There is an indication that with very susceptible (i.e. early harvested) fruit, a higher concentration than 1·8 mg per 10 in. square is necessary for complete control. This conforms with the results of E. G. Hall (private communication 1959), who showed that the concentration of DPA required to effect complete control should be varied with the susceptibility of the fruit to the disorder.

Though effective control of superficial scald on very susceptible fruit may be obtained by the use of DPA of appropriate strength, DPA treatment does not reduce the incidence of some other serious storage disorders in early-picked fruit. However, DPA does appear to effect some reduction in the incidence of internal breakdown.

Of the compounds tested because of their similarity in properties or structure to DPA, five have given effective control of superficial scald in various experiments. These are 6 ethoxy 12 dihydro 224 trimethylaquinoline, p hydroxydiphenylamine, diphenylcarbamychloride, N phenyl 1 napththylamine, and NN′ diphenyl p phenylenediamine. In view of the doubtful position with regard to the toxicity of DPA to human beings in the form of residues on fruit, these compounds are worthy of further study. It is interesting to note that 6 ethoxy 12 dihydro 224 trimethylquinoline has been cleared by the United States Food and Drug Administration for commercial use on apples.

Throughout the series of experiments, little information as to the cause of superficial scald or the manner of action of the effective inhibitors of scald development was obtained.

However, it appears significant that diphenylamine 6 ethoxy 12 dihydro 224 trimethylquinoline and NN′ diphenyl p phenylenediamine have been used as anti-oxidants for B-carotene in stock feeds and that phenothiazine, claimed to have scald-controlling properties on some overseas apple varieties, also has been used for the same purpose. It therefore appears that an investigation into the role of B-carotene in scald incidence may be of value in determining the cause of this disorder. Another avenue worthy of consideration is the examination of bisphenol derivatives as controllers of superficial scald, as their value as antioxidants for carotene has been demonstrated by Bickoff, Livingston, and Thompson (1955).

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ESTABLISHMENT OF KIKUYU GRASS ON THE CLAY SOILS OF THE DARLING DOWNS, SOUTH-EASTERN QUEENSLAND

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SUMMARY

Trials were conducted to determine the relative influence of size of sprig, depth of planting and time of planting on the establishment of kikuyu grass. The trials extended from August to February and were conducted on a dark grey clay soil of the Irving-Purrawunda Soil Association.

The best establishment followed late winter planting. Establishment increased with size of sprig (from 3 nodes to 9 nodes) but decreased with increase in depth of planting from 2 in. to 6 in. The rate of surface colonization followed the pattern of establishment.

I. INTRODUCTION

One of the primary problems in the application of soil conservation measures is the provision of erosion-resistant vegetation. This is particularly the case in areas where concentrated flows of water occur.

On the Darling Downs, in south-eastern Queensland, the provision of water disposal channels or waterways is the first step in the establishment of the agricultural drainage pattern. These waterways are generally constructed on sites where run-off water accumulates naturally and are designed to carry water at velocities which exceed the maximum non-scouring velocities of bare soils. It is therefore necessary that these waterways be protected by an erosion-resistant cover of vegetation.

Since no further soil conservation earthworks can be constructed until the channel is stabilized, it is important that this be effected as rapidly as possible.

Experience has shown that for most areas of the Darling Downs kikuyu grass (*Pennisetum clandestinum* Hochst.) provides the most effective cover for these waterways.

Because there is no commercial supply of seed, the grass is established from vegetative material, either sprigs or turves. The labour involved in collecting, transporting and then hand-planting sprigs or turves is considerable. To mechanize planting, a kikuyu sprig planter has been developed by officers of the Department of Agriculture and Stock. The machine is a modification of the American Bermuda sprig planter. It plants two rows 45 in. apart, and approximately 4–5 ac can be planted in a normal working day.

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The sprig planting method is now extensively used for establishing waterway vegetation on the Darling Downs, but information has been lacking on the optimum size of sprig to plant, the depth to which sprigs should be planted, and the best time of the year to plant having regard to growth rate and soil conservation needs.

The sprig planter buries the whole of the sprig. This contrasts with the normal hand-planting method where approximately two-thirds of the sprig is buried and one-third is left protruding from the surface. However, it has been shown that complete establishment is possible on the Darling Downs where the whole sprig is buried to a depth of 2-3 in. provided moisture and temperature conditions are satisfactory.

The months of February and March would appear to offer the best conditions for the planting of vegetative material. Establishment is rapid provided follow-up rain occurs within a fortnight after planting. However, the high temperatures cause rapid drying of the disturbed soil with consequent desiccation and death of the sprig if this follow-up rain does not come. This occurs even with compaction of the soil immediately after planting. Consideration was given to the fact that the much lower evaporation losses in late winter might enable more reliable establishment provided the low temperatures did not inhibit establishment. At this time of the year establishment could proceed during a period when erosion-producing rains were infrequent and the risk of loss of planting material reduced. Further, surface cover from late-winter plantings should be sufficiently well developed to provide soil protection against the high-intensity rains of midsummer. This situation has much to recommend it from a soil conservation viewpoint.

II. EXPERIMENTAL

Trials based on size of planting material, depth of planting and time of planting were carried out.

(1) *Planting Material.*—Rhizomes were selected visually for uniformity and then cut to three sizes based on number of nodes rather than length, although material of both extremes of short and long internode length was discarded. Three-, 6- and 9-node material was used (Figure 1). Fifty sprigs were hand-planted in each plot approximately 1 ft apart.

(2) *Method and Depth of Planting.*—Sprigs of each length were planted by hand to depths of 2, 4 and 6 in. The 2 in. planting was in a furrow (Figure 2) opened to 2 in. by hand-mattocking. The 4 in. and 6 in. depths were obtaining by opening holes to the required depth using a 4 in. soil auger (Figure 3). Care was taken to cover the sprigs by returning the soil to the holes as close as practicable to its original location—i.e. the dry surface mulch (if present) was replaced on the surface after the moister lower soil levels were returned to their original positions. The soil was then compacted over the sprig by tramping.

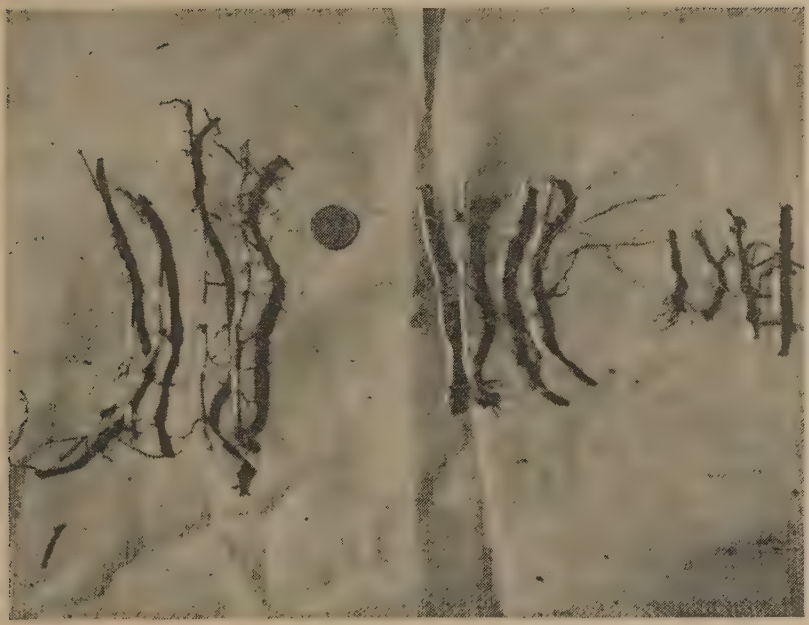

Fig. 1.—Typical planting material used in the trial. Left to right, 9-, 6- and 3-node rhizomes.

Fig. 2.—Planting sprigs to a depth of 2 in.

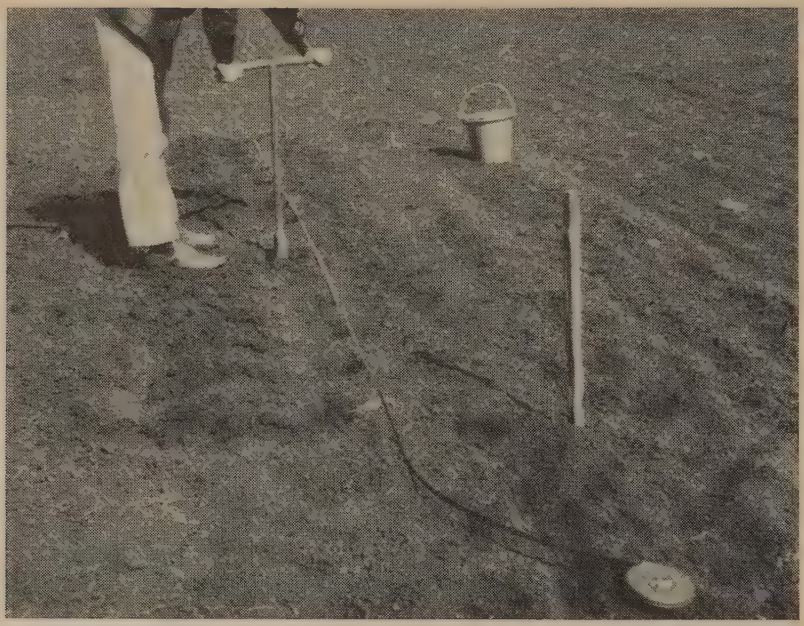

Fig. 3.—Preparing holes for sprig planting at 4 in. and 6 in. depths. Moist soil was replaced over the planted sprigs.

(3) *Condition of Soil.*—All trials were conducted on an area of a dark grey clay soil (self-mulching Irving-Purrawunda Soil Association) (Figure 4). The area was bare fallowed during the summer of 1957-58. It was in good tilth and held good subsoil moisture at each planting.

(4) *Time of Trial Initiation.*—Six 9 x 3 randomized block trials were conducted with planting times as follows: August 1-2, 1958; September 4-5, 1958; October 9-10, 1958; December 3-4, 1958; January 6-7, 1959; and February 10-13, 1959.

(5) *Method of Assessment.*—Plant counts were taken at intervals and a final count was made approximately four months after planting. After this period, differentiation of individual plants became impracticable due to surface spread. In cases where good initial establishment was obtained and rapid growth followed, a complete cover resulted in less than four months. Counts were therefore discontinued at this stage or at four months in the case of the backward treatments.

(6) *Colonization Data.*—Colonization data were not collected in detail but were recorded at important stages in some trials (Figure 5). Data for the August planting are presented in Table 8.

Fig. 4.—General view of the area on which the trials were conducted.

Fig. 5.—Quadrat used for collecting colonization data. Quadrat 36 in. square divided into 324 squares.

(7) *Rainfall.*—Details of rainfall over the period of the trial are as follows:—

Month	No. of Falls	Largest Fall (in.)	Total (in.)
1958			
July	3	0·61	0·69
August	6	0·54	1·37
September	4	0·54	0·95
October	5	1·58	3·62
November	5	0·20	0·37
December	10	0·66	2·70
1959			
January	12	1·78	4·51
February	7	2·75	3·62
March	6	1·53	2·93
April	6	0·55	1·45
May	5	0·84	1·29
June	2	0·12	0·17

III. RESULTS

The results are summarized in Tables 1–9 and Figures 6–10.

(a) Size of Planting Material

In all trials the 9-node rhizome establishment exceeded the 3-node rhizome establishment at the 1% level of significance. In the October and January series the 9-node rhizome establishment exceeded the 6-node rhizome establishment at the 1% level and in the August and December series at the 5% level. In the August, September, October, December and January trials the 6-node rhizome establishment exceeded that of the 3-node rhizomes at the 1% level and in February at the 5% level.

TABLE 1

ANALYSIS OF RHIZOME ESTABLISHMENT—AUGUST PLANTING
SUMMARY OF MEAN VALUES

No. of Nodes	$\sqrt{x + \frac{1}{2}}$ for Depth				Equivalent No. for Depth			
	2 in.	4 in.	6 in.	Mean	2 in.	4 in.	6 in.	Mean
9	6·38	6·60	5·95	6·31	40·2	43·1	34·9	39·3
6	6·04	5·52	5·04	5·53	36·0	30·0	24·9	30·1
3	5·33	4·42	2·96	4·24	27·9	19·0	8·3	17·5
Mean	5·92	5·51	4·65	5·36	34·5	29·9	21·1	28·2

	S.E.	Nec. Diff. 5%	Nec. Diff. 1%		
Individual	·361	1·08	1·49	9> 6>>3	No. of nodes
Marginal	·208	·62	·86	2, 4>> 6	Depth

Further analysis shows that in every trial month and at every depth, 9-node rhizomes were equal to or better than 6-node rhizomes, and except in the February planting, at the 6 in. depth, were significantly better than 3-node rhizomes.

TABLE 2

ANALYSIS OF RHIZOME ESTABLISHMENT—SEPTEMBER PLANTING
SUMMARY OF MEAN VALUES

No. of Nodes	$\sqrt{x + \frac{1}{2}}$ for Depth				Equivalent No. for Depth			
	2 in.	4 in.	6 in.	Mean	2 in.	4 in.	6 in.	Mean
9	3·96	4·59	3·61	4·05	15·2	20·6	12·5	15·9
6	2·87	4·60	3·05	3·51	7·7	20·7	8·8	11·8
3	2·50	2·08	1·43	2·00	5·8	3·8	1·5	·3·5
Mean	3·11	3·76	2·69	3·19	9·2	13·6	6·7	9·7

	S.E.	Nec. Diff. 5%	Nec. Diff. 1%		
Individual	·399	1·20	1·65	9, 6>> 3	No. of nodes
Marginal	·230	·69	·95	4 >> 6	Depth

TABLE 3

ANALYSIS OF RHIZOME ESTABLISHMENT—OCTOBER PLANTING
SUMMARY OF MEAN VALUES

No. of Nodes	$\sqrt{x + \frac{1}{2}}$ for Depth				Equivalent No. for Depth			
	2 in.	4 in.	6 in.	Mean	2 in.	4 in.	6 in.	Mean
9	5·22	3·93	3·36	4·17	26·7	14·9	10·8	16·9
6	4·99	3·28	1·87	3·38	24·4	10·3	3·0	10·9
3	2·91	1·46	1·05	1·81	8·0	1·6	0·6	2·8
Mean	4·37	2·89	2·09	3·12	18·6	7·9	3·9	9·2

	S.E.	Nec. Diff. 5%	Nec. Diff. 1%		
Individual	·099	·99	1·36	9>> 6>> 3	No. of nodes
Marginal	·057	·57	·79	2>> 4>> 6	Depth

(b) Depth of Planting

At the 1% level of significance the strike at the 2 in. depth of planting significantly exceeded that at the 4 in. and 6 in. depths in the October and January trials and that at the 6 in. depth in the August, October, December, January and February trials. The 4 in. depth of planting significantly exceeded the 6 in. depth at the 1% level in the August, September, October, January and February trials.

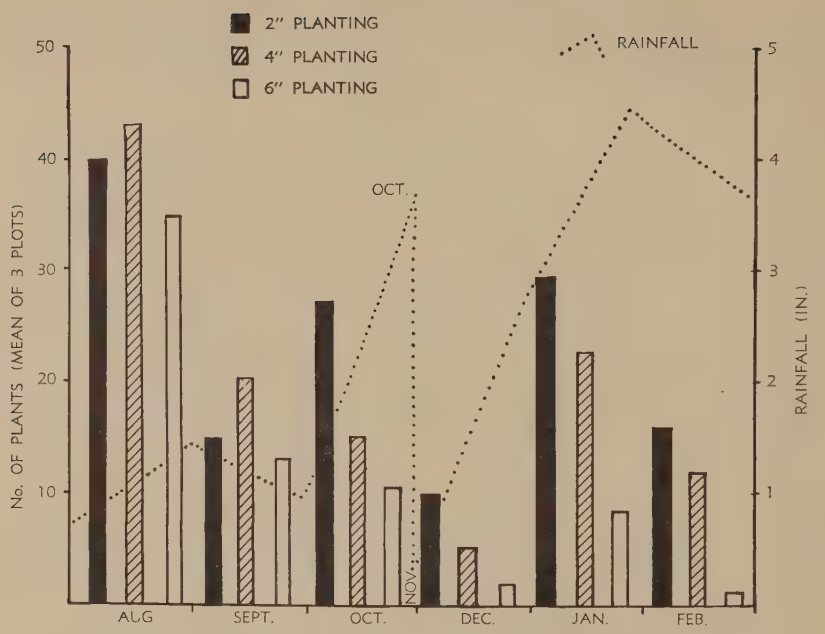

Fig. 6.—Establishment from 9-node rhizomes.

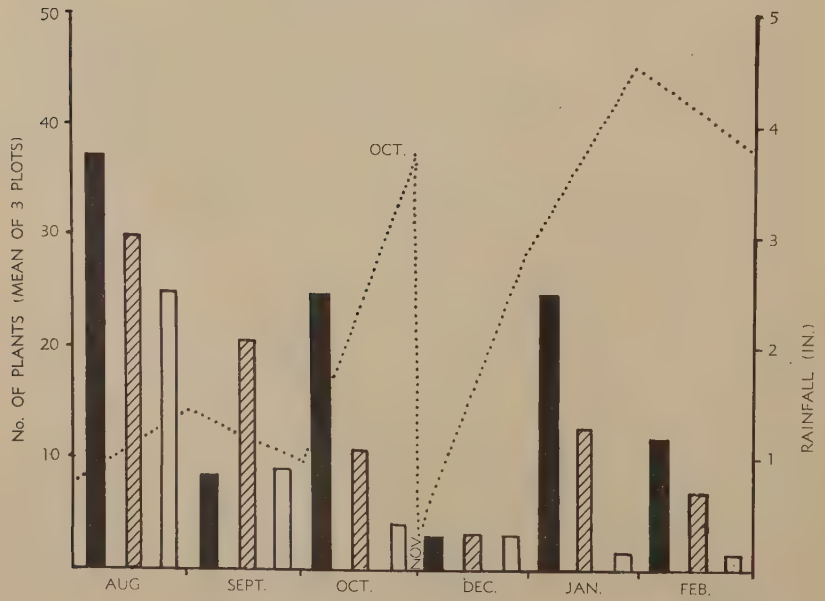

Fig. 7.—Establishment from 6-node rhizomes. (Legend as in Fig. 6.)

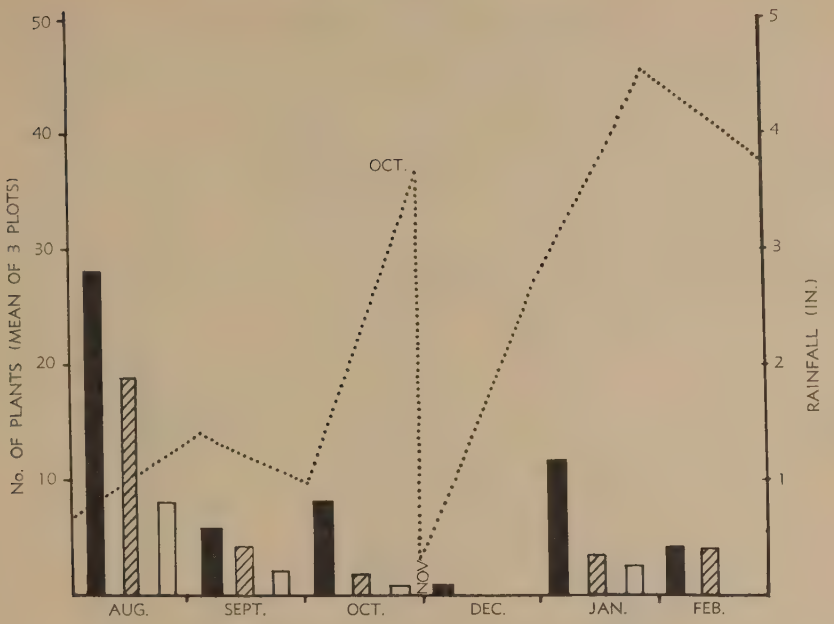

Fig. 8.—Establishment from 3-node rhizomes. (Legend as in Fig. 6.)

These results show the inferiority of the 6 in. depth of planting to the 4 in. depths. If the 9-node rhizome is accepted as the best planting material, then for this length we find that the 2 in. depth was better than the 4 in. in three months and equal to 4 in. in the other three months.

The relationship between the depth of planting and the size of material planted is shown in Figure 9.

TABLE 4

ANALYSIS OF RHIZOME ESTABLISHMENT—DECEMBER PLANTING
SUMMARY OF MEAN VALUES

No. of Nodes	$\sqrt{x + \frac{1}{2}}$ for Depth				Equivalent No. for Depth			
	2 in.	4 in.	6 in.	Mean	2 in.	4 in.	6 in.	Mean
9	3·16	2·26	1·39	2·27	9·5	4·6	1·4	4·7
6	1·76	1·74	1·65	1·72	2·6	2·5	2·2	2·4
3	1·22	0·88	0·88	0·99	1·0	0·3	0·3	0·5
Mean	2·05	1·63	1·31	..	3·7	2·1	1·2	..

	S.E.	Nec. Diff. 5%	Nec. Diff. 1%		
Individual	·263	0·79	1·09	9> 6>> 3	No. of nodes
Marginal	·152	0·46	0·63	2 >> 6	Depth

TABLE 5

ANALYSIS OF RHIZOME ESTABLISHMENT—JANUARY PLANTING

SUMMARY OF MEAN VALUES

No. of Nodes	$\sqrt{x + \frac{1}{2}}$ for Depth				Equivalent No. for Depth			
	2 in.	4 in.	6 in.	Mean	2 in.	4 in.	6 in.	Mean
9	5·47	4·81	2·96	4·41	29·4	22·7	8·2	19·0
6	4·99	3·67	1·56	3·41	24·4	13·0	1·9	11·1
3	3·51	1·68	1·46	2·22	11·8	2·3	1·6	4·4
Mean	4·66	3·39	1·99	..	21·2	11·0	3·5	..

	S.E.	Nec. Diff. 5%	Nec. Diff. 1%		
Individual	·312	0·93	1·29	9>> 6 >> 3	No. of nodes
Marginal	·180	0·54	0·74	2 >> 4 >> 6	Depth

TABLE 6

ANALYSIS OF RHIZOME ESTABLISHMENT—FEBRUARY PLANTING

SUMMARY OF MEAN VALUES

No. of Nodes	$\sqrt{x + \frac{1}{2}}$ for Depth				Equivalent No. for Depth			
	2 in.	4 in.	6 in.	Mean	2 in.	4 in.	6 in.	Mean
9	4·05	3·47	1·00	2·85	16·2	11·5	0·5	7·6
6	3·43	2·74	1·32	2·50	11·3	7·0	1·3	5·7
3	2·16	1·87	0·71	1·58	4·2	3·0	0·0	2·0
Mean	3·23	2·69	1·01	..	9·9	6·7	0·5	..

	S.E.	Nec. Diff. 5%	Nec. Diff. 1%		
Individual	·411	1·23	1·70	9 >> 3 ; 6 > 3	No. of nodes
Marginal	·237	0·71	0·98	2, 4 >> 6	Depth

TABLE 7

ANALYSIS OF RHIZOME ESTABLISHMENT—AVERAGE OVER SIX PLANTINGS

SUMMARY OF MEAN VALUES

No. of Nodes	$\sqrt{x + \frac{1}{2}}$ for Depth				Equivalent No. for Depth			
	2 in.	4 in.	6 in.	Mean	2 in.	4 in.	6 in.	Mean
9	4·71	4·28	3·04	4·01	21·7	17·8	8·8	15·6
6	4·01	3·59	2·41	3·34	15·6	12·4	5·3	10·7
3	2·94	2·06	1·41	2·14	8·1	3·8	1·5	4·1
Mean	3·89	3·31	2·29	..	14·6	10·5	4·7	..

	S.E.	Nec. Diff. 5%	Nec. Diff. 1%		
Individual	·214	0·67	0·96	9 >> 6 >> 3	No. of nodes
Marginal	·104	0·33	0·47	2, 4 >> 6	Depth

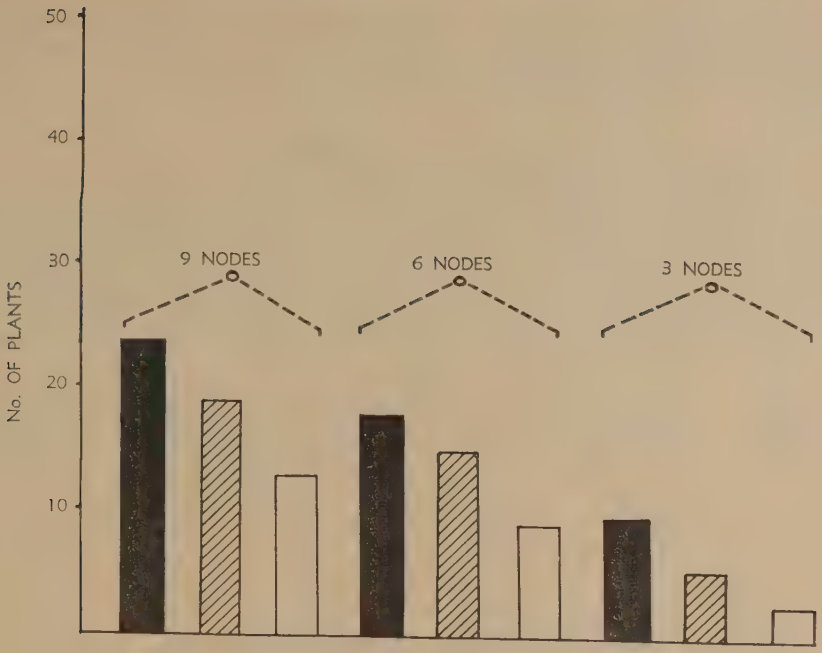

Fig. 9.—Mean establishment of six trial plantings. (Legend as in Fig. 6.)

(c) Time of Planting

Figures 6–8 show the relationship of size of rhizome and depth of planting for the six trials, with the rainfall plotted on a monthly total basis. The July and August rainfalls were the lowest monthly totals over the trial period other than for November.

The establishment rate in August was highest in all the treatments. This is considered to be due to the low soil moisture evaporation rate of July and August and a corresponding higher soil moisture level at the depth of sprig establishment. In contrast is the poor establishment in the December and February trials under conditions of high soil moisture evaporation lossess and inadequate moisture replacement from rainfall during the critical period of viability of the rhizomes.

From the trial results it appears that the establishment of kikuyu grass on the Darling Downs during the late winter months is practicable. The results obtained under higher rainfall conditions during the midsummer months of January and February were significantly inferior to the August results. In August the establishment resulted from soil moisture retained in the upper profile due to low seasonal evaporation and was not dependent on increment in moisture from rainfall. It is generally possible by prior fallowing to provide this moisture for

a June-July-August planting and correspondingly on the trial evidence to establish kikuyu grass sprigs with a minimum danger of plant mortality without follow-up rain. This cannot be done in the summer months.

(d) Rate of Colonization

Colonization data collected from the August trial 18 weeks after planting showed that the surface growth of the 9-node rhizomes significantly exceeded that of the 6-node rhizomes at the 1% level of significance for the 4 in. depth of planting and at the 5% level for the 6 in. depth of planting. The surface growth for the 3-node rhizomes were markedly inferior and was not included in the analysis. The difference in surface cover decreased with time.

TABLE 8

COLONIZATION RATES AT 18 WEEKS—AUGUST PLANTING

No. of Nodes	Mean Cover (%)		
	2 in.	4 in.	6 in.
9	47	43	12
6	47	12	5
3	17	3	0

Analysis of Variance (log. trans)—Summary of Mean Values

No. of Nodes	log.				Equivalent %			
	2 in.	4 in.	6 in.	Mean	2 in.	4 in.	6 in.	Mean
9	1·65	1·62	1·06	1·45	45	42	11	28
6	1·64	1·02	0·70	1·12	44	10	5	13
Mean	1·65	1·32	0·88	1·28	44	21	8	19

	S.E.	Nec. Diff.		
		5%	1%	
Individual	·099	·31	·44	9 >> 6 at 4 in.
Marginal	·057	·18	·26	9 > 6 at 6 in.

(e) Establishment

The general relationship between size of sprig, depth of planting, time of planting and establishment is shown in Figure 10 and Table 9. The time of emergence of shoots from the planted rhizomes is directly related to planting depth and size of material. The larger the planted material the quicker the emergence, and conversely the deeper the planting (from 2 in. to 6 in.) the slower the emergence. The factor of emergence is reflected in the initial colonization rate and is important in soil erosion control.

TABLE 9

MEAN OF PLANT COUNTS—AUGUST PLANTING

Treatment	Date of Plant Counts			
	26.viii.58	4.ix.58	10.x.58	9.xii.58
2-node rhizomes at 2 in.	18·7	22·5	23·7	28
3-node rhizomes at 4 in.	1·3	5·7	11	19
3-node rhizomes at 6 in.	0·3	0	1	8
6-node rhizomes at 2 in.	28·0	33·3	34	37
6-node rhizomes at 4 in.	4·3	16·3	22·5	30
6-node rhizomes at 6 in.	1·0	5	13·5	25
9-node rhizomes at 2 in.	30·7	38	38·5	40
9-node rhizomes at 4 in.	8·3	25·3	36·5	43
9-node rhizomes at 6 in.	0	5·7	13·5	35

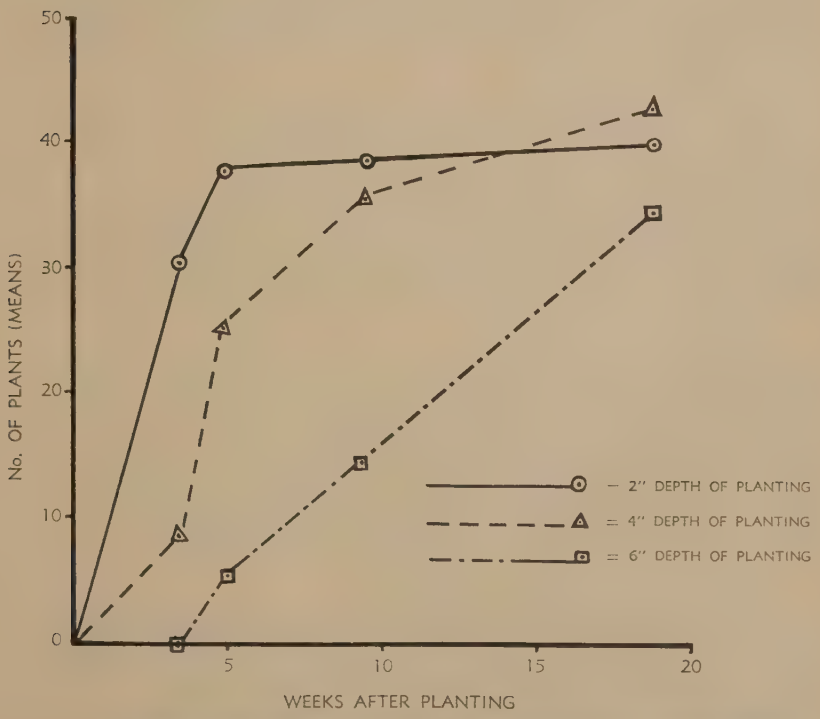

Fig. 10.—Rate of establishment of 9-node rhizomes for various planting depths (August planting).

IV. DISCUSSION

These investigations have provided data enabling certain conclusions to be drawn which are of importance in the Darling Downs soil conservation programme. These are:—

(1) The planting of kikuyu grass on soil moisture resulting from late winter or early spring rains is quite practicable and results in satisfactory plant establishment. The lower temperatures result in a slower growth rate than is the case with a midsummer planting but there is less risk of erosion-producing rains damaging the soil before surface cover is developed to a degree sufficient to provide protection against erosion.

(2) Kikuyu grass sprigs should not be planted to a depth greater than 4 in. This is important where the grass is planted mechanically either by ploughing-in or by the use of the kikuyu sprig planter.

(3) It is desirable to plant as large a piece of vegetative material as is practicable. The planting of turves is desirable but is usually impracticable for larger areas because of the quantity of material involved and labour required. The 9-node rhizome was selected as the type of sprig considered practical for delivery from a sprig planting machine.

The finding that the sprigs under nine nodes gave a much lower percentage establishment led to modification of the current model sprig planter. This involved alteration of the drum mechanism which teases out the sod into sprigs. The number of fingers on the drums was reduced by half, which resulted in the kikuyu grass sod being broken down to material of a size approaching the 9-node rhizomes used in the trial. The unmodified drum delivered a fair percentage of material approximating the 3-node size range.

These trials suggest that the following procedure should be adopted for the establishment of vegetation in soil conservation waterways on those parts of the Darling Downs where growth of kikuyu grass is satisfactory:

(1) Construct the waterway following summer rains, i.e. in autumn. When the waterway has been shaped, the section to be planted should be ripped to a depth of 6 in., leaving the surface in an open cloddy condition.

(2) Fallow the waterway during the winter.

(3) Plant kikuyu grass. The sprig planter should be set so that there will be 2–3 in. of compacted soil above the sprigs. The planted rows should be compacted by rolling with the rear wheel of a normal farm tractor. Other trials have indicated that compaction of the loose soil covering the kikuyu sprigs may considerably increase the percentage strike where soil moisture is at a doubtful level for establishment.

V. ACKNOWLEDGEMENTS

It is desired to acknowledge the assistance given by Messrs. G. and T. Wall, Rocky Creek, Pittsworth, in the conduct of these trials. Field assistance was given also by Messrs. M. H. Roberts, G. A. Bass and N. A. Rowlands. Mr. P. B. McGovern (Senior Biometrician) analysed the trial data.

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IRRIGATION CHARACTERISTICS OF SOILS IN THE MAREEBA-DIMBULAH AREA OF NORTH QUEENSLAND

1. SOIL MOISTURE CHARACTERISTICS OF THREE MAJOR SOIL TYPES

By G. D. KEEFER, B.Sc.*, and D. K. WARD, B.Agr.Sc.*

SUMMARY

Data on the field capacity, wilting point, bulk density, available soil moisture and texture of three important tobacco soils are presented.

A general description of the soils is included together with some comments on their behaviour under irrigation.

I. INTRODUCTION

The Mareeba-Dimbulah area in North Queensland is being developed as a major irrigation area.

This paper discusses basic studies on the soil moisture characteristics of three major soil types on which tobacco is being grown under irrigation. The investigations reported were conducted in conjunction with field investigations of infiltration capacity which will be reported in a subsequent paper.

II. SOIL DESCRIPTIONS

The soil types examined were originally described by officers of the Queensland Department of Agriculture and Stock in unpublished Departmental reports. They were designated:

(*a*) Walsh Sandy Clay Loam (Type 43)

(*b*) Algoma Loamy Sand (Type 32)

(*c*) Dimbulah Sandy Loam (Type 41).

These soils occupy considerable areas on the left bank of the Walsh River. In general terms, the area can be described as a fairly narrow strip running east-west and bounded on the north by the Walsh River and on the south by a range of mountains and hills. Closely related soil types occur in other sections of the irrigation scheme.

To study irrigation characteristics, representative virgin areas were selected either on or adjacent to Parada Tobacco Experiment Station. In locating these sites, the original soil survey reports were consulted. The type profile descriptions from these reports have been included in Appendix 1 for purposes of comparison.

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Field descriptions of the profiles at the selected sites are given below, together with general features of each soil type.

(a) Walsh Sandy Clay Loam (Type 43)

This alluvium forms the levee bank of the Walsh River and occupies approximately 970 ac. It gradually falls away from the river, merging into a drainage line of depression-type soils. The slope ranges from 0·5 to 1·0 per cent.

The vegetation is predominantly long-leafed box (*Eucalyptus leptophleba*) and bloodwood (*E. intermedia*), with a slight preponderance of the former. Beefwood (*Grevillea glauca*), ironwood (*Erythrophloeum chlorostachys*) and quinine berry (*Petalostigma pubescens*) also occur. Poplar (*Eucalyptus alba*) is common along the lower slopes where this soil merges into the depression soils. The principal grasses are kangaroo grass (*Themeda australis*), giant spear grass (*Heteropogon triticeus*) and bunch spear grass (*H. contortus*). Figure 1 shows typical vegetation.

Fig. 1.—Vegetation on Walsh Sandy Clay Loam. Large long-leafed box in right foreground.

Profile Description (Figure 2)

Horizon	Depth (in.)	
A1	0–12	light brown sandy loam
B1	12–54	reddish yellow clay loam—loam
B2	54–72	reddish gritty clay loam

Horizon boundaries are diffuse. Concretionary material up to ½ in. in diameter is commonly found in the surface foot.

Fig. 2.—Soil Profile—Walsh Sandy Clay Loam.

This fine-textured soil becomes hard on drying, particularly at a depth of 12–15 in., where there is a compacted layer which tends to restrict water penetration.

A type profile description is given in the Appendix.

(b) Algoma Loamy Sand (Type 32)

This soil occupies some 4,200 ac in the Left Bank Walsh area. It is a coarse sandy regosol formed from granitic material conveyed from mountains to the south and deposited in the "fill" area between the mountains and the Walsh River. The "fill" area is dissected by many minor streams and drainage lines and the Algoma soil type is associated in a complex pattern with other less desirable alluvial soils. It occurs on gentle slopes of up to 1·0 per cent.

Fig. 3.—Vegetation on Algoma Loamy Sand. Bloodwood in right foreground; pandanus and tea-tree in background.

The general area of this soil type has a very slight surface accumulation of organic matter and a very small amount of silt and clay throughout the profile. It supports a mixed open forest vegetation, chiefly bloodwood and broad-leafed tea-tree (*Melaleuca nervosa*). Beefwood, long-leafed box and quinine berry also occur and the grass cover is predominantly spear grasses.

Throughout areas of this general soil type are narrow localized ridges which have a coarse gravelly surface and support a growth of pandanus (*Pandanus* spp.) (Figure 3). On these ridges there is little or no grass cover.

Profile Description (Figure 4)

Horizon	Depth (in.)	
A1	0–4	light grey loamy sand
A2	4–10	very light grey coarse loamy sand
B1	10–72	very light grey coarse sand and gravel

The soil is extremely variable below 3 ft, with a sandy clay being the heaviest texture encountered. At the site selected, a sandy clay band approximately 4–6 in. thick occurs at a depth of 6 ft. Water movement through this layer is restricted and leads to the build-up of a perched water table.

A type profile description appears in the Appendix.

Fig. 4.— Soil profile of Algoma Loamy Sand.

(c) Dimbulah Sandy Loam (Type 41)

Of the three soils, the Dimbulah Sandy Loam occurs furthest from the Walsh River and is always confined to elevated regions. In the Left Bank Walsh area, Type 41 occupies some 5,000 ac and has a slope varying from 1·0 to 2·5 per cent.

Ironwood is characteristic of the Dimbulah Sandy Loam. Long-leafed box, bloodwood, flame tree (*Brachychiton paradoxum*) beefwood and red ash (*Alphitonia excelsa*) also occur. There is a good coverage of grass (Figure 5).

PROFILE DESCRIPTION (Figure 6)

Horizon	Depth (in.)	
A1	0–4	light brown coarse sandy loam
A2	4–15	light brown coarse sandy loam
B1	15–21	red gritty clay loam
B2	21–48	red gritty clay loam

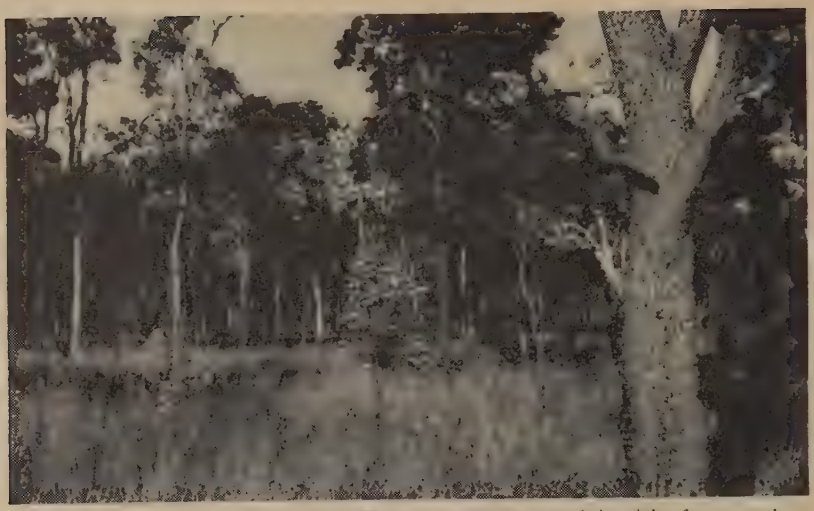

Fig. 5.—Vegetation on Dimbulah Sandy Loam. Ironwood in right foreground.

Fig. 6.—Soil profile of Dimbulah Sandy Loam.

At the selected site, the soil profile was examined to 9 ft, at which depth rock was encountered. Some red and yellow mottling was found below 5 ft and a thin pallid zone occurred at 8 ft 6 in., above free water resting on the rock material. Quartz fragments were present below 18 in.

The soil becomes sticky when wet, particularly in the B2 horizon where there is a comparatively high clay content (25 per cent.). Below 48 in. the soil is lighter in texture where increased amounts of sand and gravel occur, giving rise to sandy and gravelly clay loams.

III. METHODS

Investigations were confined to an area of 1 square chain on the representative virgin sites already described. A limited area was chosen in order to obtain some measure of the degree of variability to be expected from the various observations.

(1) *Field Capacity*.—From March to August 1959, a series of infiltration tests was conducted on the three soil types. Unbuffered ring infiltrometers were used. An area 2 ft square was cultivated to a depth of 3 in. and a 12 in. dia. ring driven through the cultivated layer to an overall depth of 5 in. Six tests (hereinafter referred to as a trial) were run simultaneously on a particular date. On completion of each trial, the rings were left in position and the surface within each ring covered by means of polythene film and a rubber band to prevent evaporation.

Field capacity is not an equilibrium value but one on a time-drainage curve (Veihmeyer and Hendrickson 1949). From preliminary trials it was decided that samples for field capacity determination should be taken at 24 hr on the Algoma, 48 hr on the Dimbulah and 72 hr on the Walsh soil types.

A tube-type soil sampler was used to collect soil samples at 6 in. intervals down the wetted profile within each ring. Soil moisture was determined gravimetrically.

(2) *Wilting Point*.—On each representative area, 24 sampling sites were chosen (6 rows each of 4 sites). Samples were collected from within the main soil horizons at each site with a 4 in. Jarret head auger. The four sub-samples per row were bulked and the composite sample ground to pass a 2 mm sieve.

Duplicate determinations were carried out on each composite sample. The method used for measuring wilting point was essentially the same as the sunflower technique described by Piper (1950).

(3) *Bulk Density*.—In these studies, bulk density was measured by the auger method (Stirk 1957). A 4 in. Jarret head auger was used to excavate soil in 8 in. intervals to a depth of 24 in. The volume of excavated soil was taken as being equivalent to the volume of the hole, dimensions of which were measured with a rule and calipers. Bulk density was obtained by dividing the oven-dry weight of soil by the field volume and the result expressed in g/c.c.

(4) *Soil Texture.*—The mineral fractions of the soils were determined by the Bouyoucos hydrometer method (Piper 1950). The silt and clay fractions were obtained from the hydrometer readings, the coarse sand fraction by sieving and weighing and the fine sand fraction by difference.

IV. RESULTS

(a) Field Capacity

The values obtained for field capacity are presented in Table 1. On the Algoma Loamy Sand, samplings below the surface foot were made at 12 in. intervals instead of the normal 6 in. intervals as there was little textural differentiation below this depth and the water applied frequently penetrated to at least 5 ft.

The infiltration trials were conducted over a range of antecedent soil moistures and for varying lengths of time, so the depth of penetration varied from trial to trial. Colman (1944) discussed field capacity as affected by depth of wetting and considered that only samples 12 in. above the wetted front are at field capacity. The figures incorporated in Table 1 were selected on comparison with antecedent soil moistures. For all three soils these figures represent samples at least 12 in. above the wetted front.

The relatively higher field capacity of the surface layer is probably due to organic matter content, particularly in the Walsh and Algoma soils.

TABLE 1

MOISTURE PERCENTAGE AT FIELD CAPACITY

Soil Type	Sampling Depth (in.)	Moisture at Field Capacity (%)	No. of Samples
(*a*) Walsh Sandy Clay Loam	0–6	19·0	55
	6–12	15·1	53
	12–18	15·5	30
	18–24	15·7	20
(*b*) Algoma Loamy Sand	0–6	10·3	69
	6–12	7·4	68
	12–24	6·6	67
	24–36	6·1	22
	36–48	6·5	15
(*c*) Dimbulah Sandy Loam	0–6	10·4	58
	6–12	9·3	57
	12–18	10·4	51
	18–24	14·5	40
	24–30	16·7	25
	30–36	16·6	20

Mean S.D. : (*a*) 1·5, (*b*) and (*c*) 1·1.

(b) Wilting Point

The results of the determination of the lower limit of available soil moisture have been summarized in Table 2.

For the Walsh and Dimbulah soils the percentage moisture at wilting point increases down the profile as the texture becomes heavier. In the case of the Algoma Loamy Sand the wilting point remains virtually unchanged below the surface horizon. The presence of a small amount of organic matter in the surface few inches would account for the higher moisture percentage in this layer.

TABLE 2

MOISTURE PERCENTAGE AT WILTING POINT

Soil Type	Sampling Depth (in.)	Wilting Point* (%)
(*a*) Walsh Sandy Clay Loam	3–6	4·5
	14–18	7·9
	24–27	10·4
(*b*) Algoma Loamy Sand	0–3	2·2
	6–9	1·6
	21–24	1·5
(*c*) Dimbulah Sandy Loam	0–3	2·6
	6–9	2·5
	15–18	4·9
	21–24	10·9

Mean S.D. : (*a*) 0·4, (*b*) 0·2, (*c*) 0·5.
* Mean of 12 determinations.

(c) Bulk Density

For this measurement the auger method was adopted. Although this method tends to give slightly higher results than the more conventional methods (Tisdall 1951), it was considered to be sufficiently accurate for these investigations. Stirk (1957) stated that "reasonable accuracy is obtained provided that depth intervals of not less than about 15 cms are used". In measuring the bulk density of these three soils, increments of approximately 8 in. were taken. The results (Table 3) are the means of six determinations per depth.

TABLE 3

BULK DENSITY MEASUREMENTS
(g/c.c.)

Soil Type	0–8 in.	8–16 in.	16–24 in.
(*a*) Walsh Sandy Clay Loam ..	1·34	1·66	1·76
(*b*) Algoma Loamy Sand ..	1·43	1·63	1·69
(*c*) Dimbulah Sandy Loam ..	1·55	1·58	1·52

Mean S.D. : (*a*) 0·04, (*b*) 0·11, (*c*) 0·05.

(d) Available Soil Moisture

The results from Tables 1–3 are summarized in Table 4 at depths corresponding to the different soil horizons.

TABLE 4

Available Soil Moisture and Mechanical Analyses

Soil Type	Horizon	Depth (in.)	Available Soil Moisture					Mechanical Analyses				Texture
			Field Capacity (%)	Wilting Point (%)	Available Soil Moisture (%)	Bulk Density (g/c.c.)	Available Soil Moisture (in./ft)	Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	
(*a*) Walsh Sandy Clay Loam ..	A1	0–12	17·0	4·5	12·5	1·34	2·01	13	59	19	9	LS
	B1	12–24	15·6	7·9	7·7	1·71	1·58	9	53	17	21	L
(*b*) Algoma Loamy Sand	A1	0–4	10·3	2·2	8·1	1·43	1·39	79	14	4	3	S
	A2	4–10	7·4	1·6	5·8	1·43	0·99	79	15	4	2	S
	B1	10–72	6·4	1·5	4·9	1·66	0·98	73	20	4	3	S
(*c*) Dimbulah Sandy Loam ..	A1	0–4	10·4	2·6	7·8	1·55	1·45	54	38	5	3	LS
	A2	4–15	9·8	2·5	7·3	1·58	1·38	47	44	4	5	LS
	B1	15–21	12·4	4·9	7·5	1·52	1·37	46	35	5	14	SL
	B2	21–48	16·6	10·9	5·7	1·52	1·04	36	31	8	25	SCL

Included in this table is the distribution of the mineral fractions down the soil profile. Clay content increases with depth in both the Dimbulah and Walsh soils, while the percentage clay of the Algoma is relatively small and constant. The Walsh soil type is composed mainly of fine material (less than 0·2 mm dia.), whereas coarse sand predominates in the Algoma. Fine and coarse sand fractions of the Dimbulah Sandy Loam are relatively evenly distributed and tend to decrease with depth. The type locality of the Walsh Sandy Clay Loam, which occurs nearer the headwaters of the river, tends to be heavier in texture than at the selected site.

V. DISCUSSION

Data on mechanical analysis and available moisture per foot of soil are given in Table 4. For all three soils the surface horizon has the highest available soil moisture. In the case of the Algoma soil type this is probably due entirely to the accumulation of organic matter in the surface 4 in. In the case of the other two soil types it is probably the result of the combined effect of texture and organic matter content.

It will be noted that while increasing clay content raises the field capacity, it increases wilting point to an even greater degree, thereby reducing the storage potential for available moisture. A comparison of the B1 and B2 horizons of the Dimbulah Sandy Loam reveals this point clearly.

An increase in the proportion of silt and fine sand has a more marked effect on the storage potential for available moisture, as these two fractions raise the field capacity appreciably without affecting the wilting point to any extent.

The amount of available water necessary to ensure economic utilization of a soil is dependent to a large extent upon the climatic conditions which prevail during the irrigation season. The U.S. Bureau of Reclamation (1947) considers that soils require at least 0·75 in. of available water per foot for economic management in comparatively arid environments. In more humid environments, irrigation may be practicable with reserves of approximately 0·5 in. per ft. The soils examined occur in a region with an average annual rainfall of 27 to 35 in., of which approximately 81 per cent. falls from December to March. It would appear that these soils fill the above requirements adequately.

Of the three soil types, the Algoma Loamy Sand has the lowest range of available moisture and would require frequent light applications of irrigation water. A sandy clay layer is often encountered on this soil type at depths below 3 ft. The soil horizons above this layer are very permeable and there is a danger of waterlogging if inefficient irrigation practices are employed.

The Dimbulah Sandy Loam and Walsh Sandy Clay Loam have favourable moisture-retaining properties and are well-drained.

The potential under continued irrigation of these three soils is sound provided attention is given to efficient irrigation techniques and farming practices.

VI. ACKNOWLEDGEMENTS

The authors wish to acknowledge the use of facilities and equipment provided by the Tobacco Industry Trust Account.

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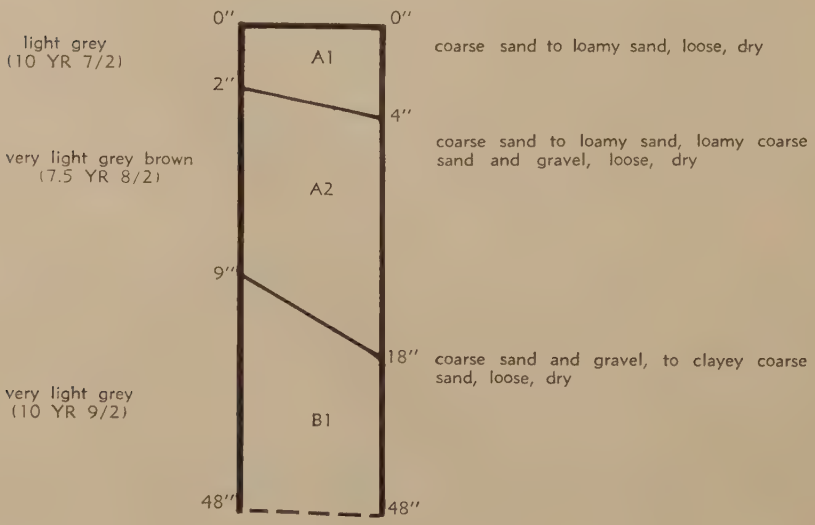
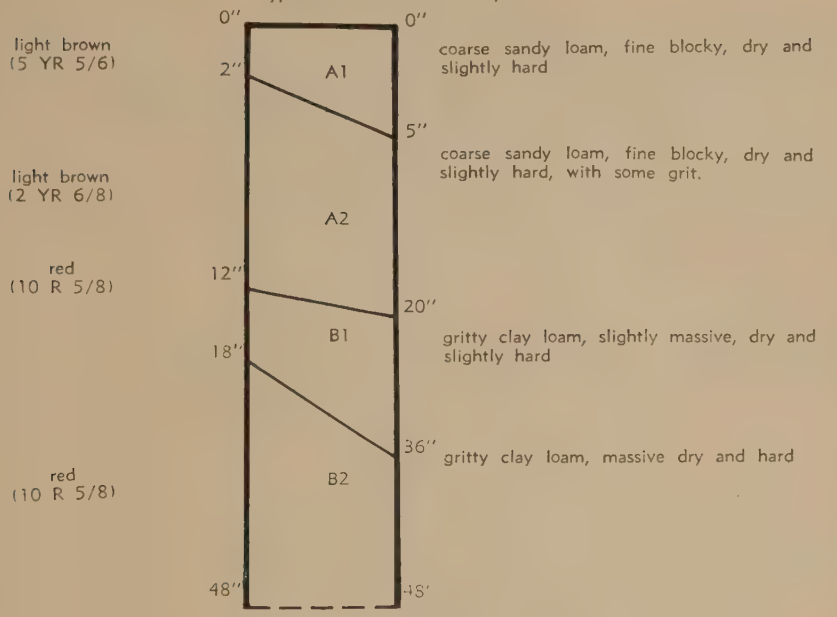
APPENDIX

The type profile descriptions of Walsh Sandy Clay Loam, Algoma Sandy Loam, and Dimbulah Sandy Loam, taken from unpublished Soil Survey Reports of the Queensland Department of Agriculture and Stock, are given below.

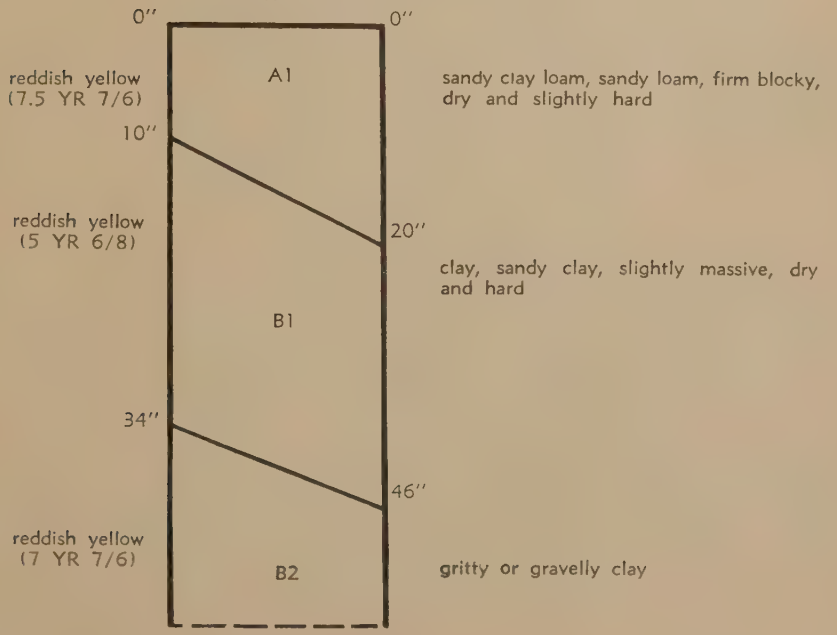
Type 32—Algoma Loamy Sand



Type 41—Dimbulah Sandy Loam



Type 43—Walsh Sandy Clay Loam



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IRRIGATION CHARACTERISTICS OF SOILS IN THE MAREEBA-DIMBULAH AREA OF NORTH QUEENSLAND

2. INFILTRATION AND RELATED DATA FOR THE CRAIG LOAMY SAND

By D. K. Ward, B.Agr. Sc.*

SUMMARY

Soil moisture relationships and infiltration characteristics of the Craig Loamy Sand are discussed and techniques used in these investigations are described. A description of the soil profile and general topographical features of the locality is also given.

I. INTRODUCTION

During 1960 from April to August infiltration studies were conducted on the soil type described in Departmental Soil Survey Reports as the Craig Loamy Sand (Type 47). This soil occurs in the vicinity of Craig Creek in the Left Bank Walsh area to the west of Mareeba. Unbuffered ring infiltrometers were used to determine the soil's infiltration characteristics.

A portion of this area was opened up for the growing of tobacco under irrigation during the 1960-61 season. The soil's nutritional requirements and general cropping ability had previously been investigated by officers of the Department of Agriculture and Stock stationed at Parada Tobacco Experiment Station. To supplement the data obtained, the absorption rate and moisture retaining properties of the soil were examined.

II. SOIL DESCRIPTIONS

The Craig Loamy Sand occupies approximately 700 ac in an area between Fumar and Chirean on the Mareeba-Dimbulah road. The topography varies in slope from 2·5 to 5.0 per cent. and in places is dissected by small watercourses which flow only during the wet season. In this locality the annual rainfall is about 32 in., 84 per cent. of which falls between December and March.

The vegetation consists principally of long-leafed box (*Eucalyptus leptophleba*) and bloodwood (*E. intermedia*), with pandanus (*Pandanus* spp.), flame tree (*Brachychiton paradoxum*) and broad-leafed tea-tree (*Melaleuca nervosa*) also occurring. In places white cypress pine (*Callitris glauca*) is quite common. *Panicum decompositum* provides the principal grass cover.

* Agronomist, Queensland Department of Agriculture and Stock.

PROFILE DESCRIPTION (Figure 1)

(This description was compiled near the test area.)

Horizon	Depth (in.)	
A1	0- 3	pale brown fine loamy sand.
A2	3-14	pale yellow fine loamy sand.
B1	14-38	yellow sandy clay loam, concretionary.
B2	38-60	red and yellow mottled sandy clay.

Some concretions and a few large stones are present in the upper part of the B1 horizon, and below 28 in. there is a concentration of concretionary material approximately 10 in. thick above the sandy clay. Throughout the area the sandy clay layer varies in occurrence from the surface, with the shallowest observed depth being 2 ft.

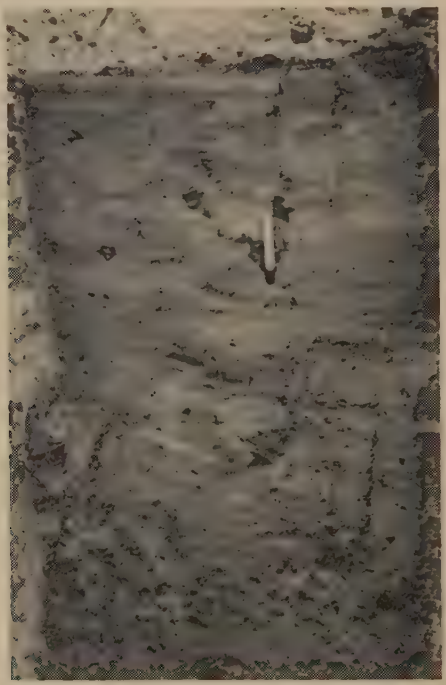

Fig. 1.—Soil profile of Craig Loamy Sand, showing concretionary material in lower B1 horizon.

III. METHODS

All investigations on the Craig Loamy Sand were confined to a virgin area of 0·1 ac to conform with the area selected on other soil types where similar studies were made.

(1) *Infiltration Studies.*—The measurement of infiltration rate *in situ* usually involves either the surface ponding of water or the spraying of water onto the surface at a rate sufficient to cause run-off. On the Craig Loamy Sand a pondage method using 9 in. x 12 in. dia. unbuffered rings was employed. This method (Stirk 1951) was used as both water and equipment had to be transported considerable distances. Also it was considered that rates obtained by this method could be applied to furrow irrigation.

The soil was first cleared of all vegetation and hand-cultivated over an area of 2 ft square to a depth of 3 in. This procedure was adopted as the infiltration trials were being conducted on a soil which was to be cultivated in practice. The ring was then driven through this loosened layer and into 2 in. of the undisturbed subsoil. A constant head of water was maintained within the ring by a "spreader" connected to the outlet pipe of the infiltrometer drum. Attached to the side of the drum was a glass tube and scale enabling the water level to be read periodically. The set-up of the equipment is shown in Figure 2.

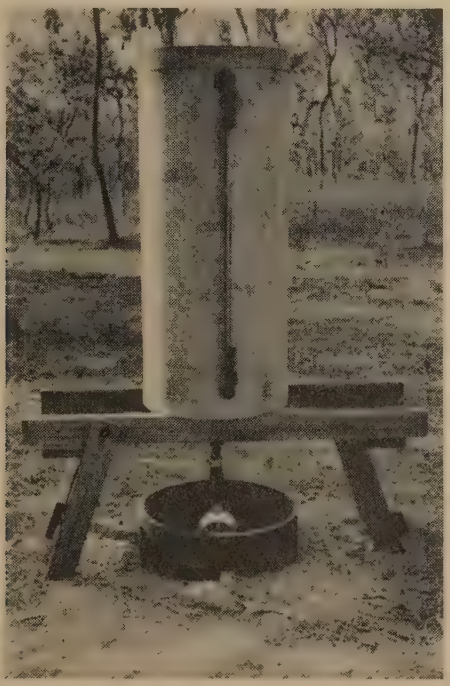

Fig. 2.—Infiltrometer for measuring infiltration rates of soils.

In these studies, eight infiltration trials were conducted on the selected area. Each trial consisted of running six infiltrometers simultaneously on a particular date. The trials were run for periods of approximately 6 hr, but one trial was

run for 12 hr to ascertain if there was any appreciable drop in infiltration rate over the prolonged period. The six infiltrometers were placed in two rows about 12 ft apart, with 12 ft spacings within the rows.

Soil samples were taken for the gravimetric determination of soil moisture prior to the commencement of each trial. Four sets of samples were collected within the test area at 4 in. depths to at least 40 in. and the average of these was taken as the antecedent soil moisture. During the period the eight trials were conducted the antecedent soil moisture decreased from 4 per cent. to 1 per cent. within the surface foot.

(2) *Field Capacity*.—Field capacity was measured in the field in conjunction with infiltration trials. On completion of these trials the rings were covered to prevent evaporation. Preliminary studies had indicated that the most suitable time for soil sampling down the wetted profile was 24 hr after the completion of infiltration trials and this sampling time was adhered to throughout the duration of these studies.

A 1·5 in. dia. tube was used for collecting soil samples from within the centre of each ring at 4 in. depths to the maximum depth of water penetration. The figures obtained down the moistened profile to within 8 in. of the wetted front were taken as being representative of the soil's field capacity. In infiltration tests the applied water frequently penetrated to a depth of at least 36 in.

(3) *Wilting Point*.—The area of 1 chain square was divided into 8 equal portions. From within each portion two samples were taken per horizon with a 4 in. Jarret head auger and bulked, and a single determination was made on each sample after it had been passed through a 2 mm sieve. The sunflower method (Piper 1950) was used to obtain the permanent wilting point.

(4) *Bulk Density*.—A 4 in. Jarret head auger was used to excavate soil in 8 in. depth intervals to 24 in. The excavated soil was oven-dried and weighed and the dimensions of the auger hole determined. Altogether six measurements of bulk density were made at each depth from within the selected area.

(5) *Soil Texture*.—Mechanical analyses were carried out on soil samples collected from the main horizons within the surface 3 ft. For these determinations the Bouyoucos hydrometer method (Piper 1950) was used.

IV. RESULTS

(a) Infiltration Studies

The infiltration rate has been defined by a committee on terminology (Richards 1952) as: "The maximum rate at which a soil, in a given condition at a given time, can absorb rain. Also, the maximum rate at which a soil will absorb water impounded on the surface at a shallow depth when adequate precautions are taken regarding border or fringe effects". It is commonly expressed in inches per hour.

By definition, infiltration rate refers to the rate at which water enters the soil, with due allowance being made for lateral spread. Marshall and Stirk (1950) described a method for correcting the minimum infiltration rate for lateral spread in small unbuffered plots. The corrected minimum infiltration rate is obtained by multiplying the actual minimum rate by the fraction of water retained directly beneath the ring.

The degree of lateral spread beneath unbuffered plots varies with duration of trial and soil type. On this sandy soil, lateral spread was considerable and resulted in only a small fraction of the applied water being retained under the ring. The average fraction retained at the end of 6 hr was only $0{\cdot}09 \pm 0{\cdot}02$.

The relationship between infiltration rate and time for the Craig Loamy Sand is presented in Figure 3, which shows the mean of the eight trials. The use of the factor 0·09 to obtain the corrected rate at all stages during infiltration is open to criticism, but the figures thus obtained enable infiltration rate, particularly minimum rate, of different soils to be compared, as the effect of lateral spread has been taken into account.

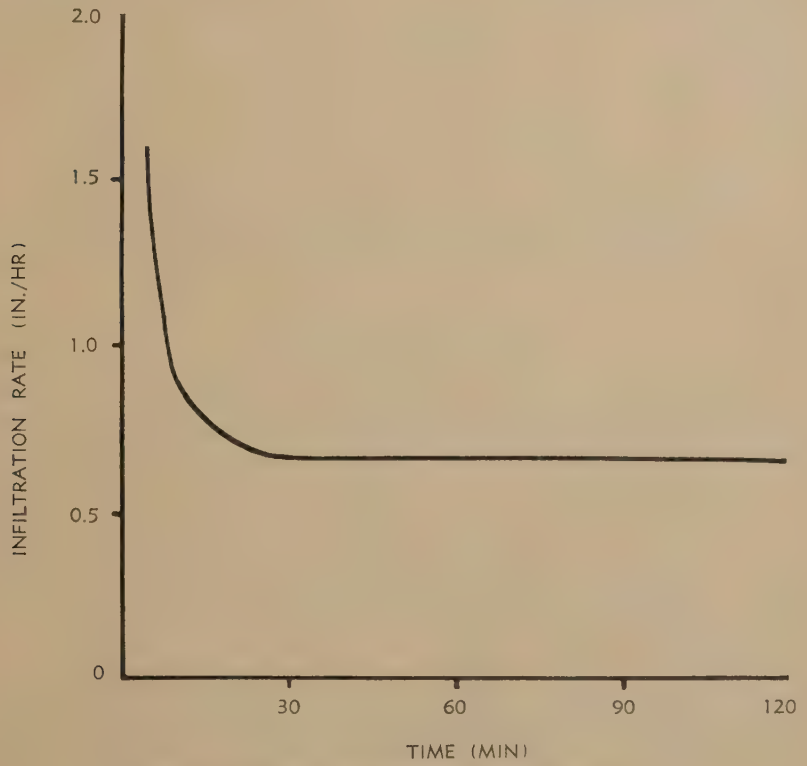

Fig. 3.—Corrected infiltration rate during period (in./hr).

Figure 3 shows the change in infiltration rate over the first 2 hr, which would be the most important period in irrigation practice. A comparatively steady rate is reached within half an hour of the initial wetting of the soil and this rate remains relatively constant for up to 6 and 12 hr. The minimum corrected infiltration rate measured was 0·67 in. per hr.

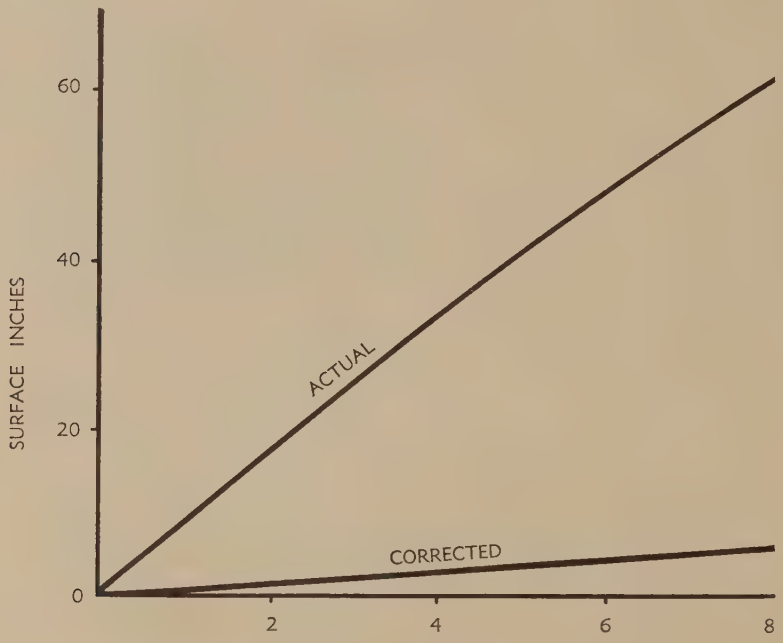

Fig. 4.—Accumulated intake.

Another aspect of the infiltration process is the total amount of water which enters the soil within a certain time interval. The graph of accumulated intake plotted against time (Figure 4) tends to continue to rise linearly for periods up to 12 hr without flattening out to any extent.

In conjunction with these infiltration trials, the moisture distribution below the ring was determined after varying amounts of water had been applied at the surface. The extent of water movement was ascertained either by exposing a vertical face of the wetted profile or by taking soil samples across the centre of the test plot.

The position of the wetted front 24 hr after applying different amounts of water is shown in Figure 5. The fraction of water retained beneath the 12 in. ring decreased with increasing amounts of water until at the end of a 6 hr trial, when over 40 in. had been applied, only 3·6 in. were retained beneath the ring.

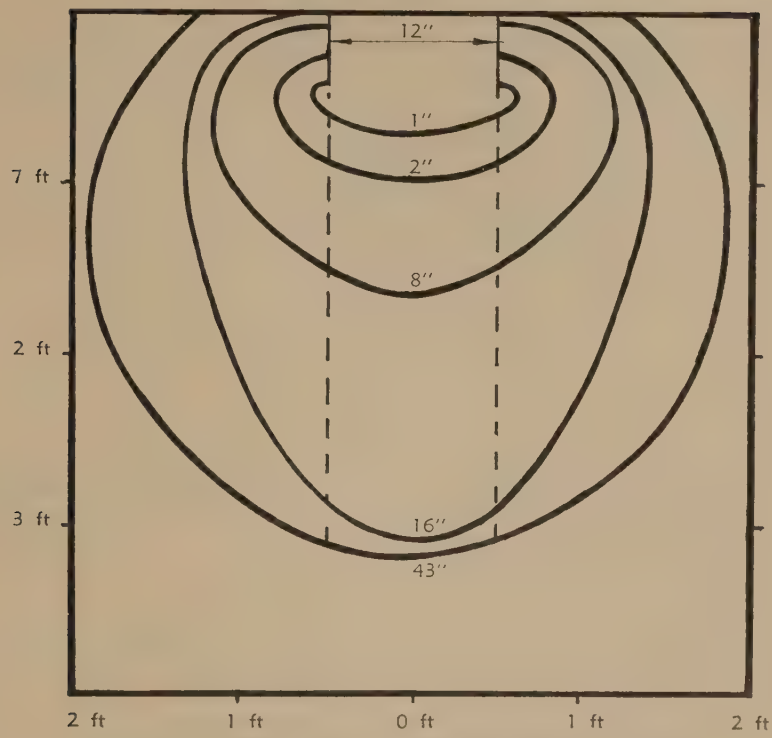

Fig. 5.—Penetration profiles in Craig Loamy Sand 24 hr after adding different amounts of water.

(b) Soil Moisture Studies

In Table 1 are presented the summarized results of available soil moisture for the Craig Loamy Sand. Although the field capacity is comparatively low (10 per cent.), there is also a correspondingly low wilting point (1 per cent.) and this results in the storage of over 1·5 in. of available moisture per foot of soil when the soil has been thoroughly wetted.

TABLE 1

AVAILABLE SOIL MOISTURE

Soil Horizon	Soil Depth (in.)	Field Capacity (%)	Wilting Point (%)	Available Soil Moisture (%)	Bulk Density (g c.c.)	Available Soil Moisture (in. ft)
A1	0–3	10·6	1·1	9·5	1·46	1·66
A2	3–14	9·2	1·2	8·0	1·57	1·51
B1	14–38	10·3	1·1	9·2	1·60	1·76

Mean S.D.: Field capacity 0·7, wilting point 0·2, bulk density 0·08.

(c) Soil Texture

The results of the mechanical analysis (Table 2) show a slight increase of silt and clay with depth and a preponderance of fine sand over coarse sand throughout the profile.

TABLE 2

MECHANICAL ANALYSIS

Horizon	Sampling Depth (in.)	Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture
A1	0–3	31	60	5	4	LS
A2	6–9	29	62	4	5	LS
B1	27–30	27	57	6	10	SL

V. DISCUSSION

The corrected infiltration data presented in Figures 3 and 4 would be applicable where spray irrigation is being used as there would be only a relatively small amount of lateral spread of water under these conditions. The results indicate that a spray application rate of not more than 0·7 in./hr would be absorbed readily provided the soil surface does not become sealed.

Under furrow irrigation, where there would be a considerable amount of lateral penetration, the actual accumulated intake (Figure 4) would bear a closer relationship to field conditions than the corrected values.

The soil appears to have favourable moisture-retaining properties and a favourable infiltration rate. However, where the sandy clay horizon is near the surface (2 ft), particular attention will need to be paid to irrigation practices.

VI. ACKNOWLEDGEMENTS

Advice and assistance received from Mr. G. D. Keefer are acknowledged as well as the use of facilities provided by the Tobacco Industry Trust Account.

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A COMPARISON OF THE COPPER STATUS OF SHEEP AND CATTLE GRAZING A PREDOMINANTLY *PASPALUM DILATATUM* PASTURE IN SOUTH-EASTERN QUEENSLAND

By J. W. Ryley, B.V.Sc., J. M. Harvey, D.Sc., J. W. Watson, B.V.Sc., and M. S. Levitt, B.Sc.*

SUMMARY

A study was made, over a period of three years, to compare the liver and blood copper concentrations of adult Hereford cattle with those of adult Merino sheep simultaneously grazing the same predominantly *Paspalum dilatatum* pastures. Blood and liver samples were taken on 15 occasions during this period.

Mean liver copper levels in cattle were less than 30 p.p.m. (D.M.) at all except one sampling, when 34.5 p.p.m. (D.M.) was recorded. Levels in sheep were greater than 100 p.p.m. for 12 of the 15 samplings. Mean blood copper levels in cattle were less than 0.08 mg/100 ml on 13 occasions, and on only 3 occasions for sheep. There was no consistent seasonal pattern in the changes in copper concentrations in liver and blood of either cattle or sheep.

Comparisons in two successive years indicated that pregnancy did not influence liver or blood copper concentrations in sheep.

Liver copper concentrations were determined in calves and lambs and their dams within 24 hr of parturition. In both cattle and sheep, liver copper concentrations in the new-born were significantly higher than in their dams. Cows with mean liver copper concentrations of 17.1 p.p.m. (D.M.) in 1957 and 9.8 p.p.m. (D.M.) in 1958 gave birth to calves with mean liver copper levels of 361 and 329 p.p.m. (D.M.) respectively. In 1957, ewes with mean liver copper levels of 103 p.p.m. (D.M.) produced lambs with mean liver copper levels of 157 p.p.m. (D.M.). In 1958, ewes giving birth to single lambs had mean liver copper levels of 134 p.p.m. (D.M.) and the levels in their lambs were 239 p.p.m. (D.M.). In the same year, the six ewes with twin or triplet lambs had liver copper levels of 141 p.p.m. (D.M.) and their lambs averaged 262 p.p.m. (D.M.).

The high liver copper concentrations in new-born calves declined rapidly in both the years studied. The rate of decline appeared to be more rapid in the year that calves grew at a faster rate. There was little decline in liver copper concentration in the growing lambs in 1957. In the next year, lambs had higher liver copper concentrations at birth, but these declined during the first four months to approximately 47 per cent. of the initial values.

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* Work conducted by the authors at Animal Research Institute, Yeerongpilly. (Queensland Department of Agriculture and Stock). J. W. Watson now with University of Queensland Veterinary School.

I. INTRODUCTION

Lee and Moule (1947) first recorded the presence of copper deficiency in livestock in Queensland, and Harvey (1952) defined a number of localities where a low copper status had been found in sheep or cattle. Sutherland (1952) reported a beneficial response to oral therapy with copper sulphate in cattle in some areas of south-eastern Queensland. The results of a survey reported by Alexander and Harvey (1957) showed that low liver or blood copper levels were found in cattle from 74·8 per cent. of 127 farms examined in coastal Queensland south of Brisbane.

Sutherland (1956) summarized the results of studies at Rocklea, near Brisbane, in which cattle with very low liver copper concentrations, grazing paspalum/white clover pastures, showed no response to parenteral copper therapy. Subsequently, when sheep were introduced to this area at Rocklea, it was noted that their liver copper concentrations remained much higher than those of the cattle.

The studies to be reported in this paper commenced in 1955. The original aim was to compare and study the seasonal variation in the liver and blood copper concentrations of sheep and cattle grazing the same paddock located on the Animal Husbandry Research Farm at Rocklea. It was noted that a marked fall in liver and blood copper concentrations occurred in ewes at the time of lambing in the first year and in consequence the experiment was modified to include studies on the effect of pregnancy and lactation on liver copper reserves in sheep. In the last two years of the experiment, copper concentrations were determined in livers of lambs and calves at birth and changes in these levels with growth were studied.

Body-weights of the animals were recorded and determinations of blood haemoglobin, packed cell volume and blood inorganic phosphate were made to define more adequately the conditions under which results were obtained.

II. MATERIALS AND METHODS

(1) *Experimental Area.*—The experimental paddock of 28·2 ac was located on the Animal Husbandry Research Farm, Rocklea, approximately 5 miles south-west of the centre of Brisbane, Queensland. The dominant pasture species in the paddock was *Paspalum dilatatum*. Line transect data obtained in June 1954 showed the following botanical composition: *Paspalum dilatatum* (paspalum) 79·3 per cent., *Digitaria didactyla* (blue couch) 3·9 per cent., *Bothriochloa decipiens* (pitted blue grass) 2·3 per cent., *Trifolium repens* (white clover) 10·2 per cent., and miscellaneous species 4·3 per cent. The proportion of white clover varied seasonally and was negligible in unfavourable seasons. The copper content obtained at monthly intervals from March 1954 to February 1955 varied from 6·5 to 8·6 p.p.m. (dry-matter basis) for paspalum and from 8·0 to 8·8 p.p.m. (dry-matter basis) for white clover.

Except for two short periods in 1956 and 1957, when portion of the ewe flock was mated, all the experimental animals continuously grazed this paddock. During joining in those years, the group to be mated and the unmated sheep were alternated at weekly intervals between the experimental and an adjacent paddock having pastures of similar botanical composition.

(2) *Experimental Animals.*—Sixteen Merino ewe weaners were obtained from the Roma district in Queensland during March 1954. They had been born during September-October 1953 and had been weaned after shearing in March 1954. No evidence of copper deficiency had been recorded on the property of origin. The animals were vaccinated against tetanus and blackleg and transferred to the experimental paddock soon after arrival. They were pregnant when the experiment commenced in June 1955, having been mated from April 22 to May 5. They had been shorn in March 1955. During the experiment, five ewes died from various causes, mainly associated with liver biopsy, and results for the portion of the experiment comparing sheep with cattle are based on the 11 ewes surviving at the end of the experiment. Most of the progeny of these ewes were retained in the experimental paddock for examination of other aspects associated with the study.

Six Hereford cows were introduced to the experiment on June 7, 1955. These animals were born in 1951 and were from a group of 46 purchased from a property at Texas in south-western Queensland and brought to Rocklea in June 1953. Since their arrival they had been grazing on pastures similar to those in the experimental area. They were non-lactating and 1-3 months pregnant when introduced to the experiment. These six cows were retained throughout the experiment and the results from them have been used in the comparisons of sheep and cattle. On July 4, 1956, a further six cows from the group purchased in 1953 were introduced to the area. These animals were non-pregnant, had calved during November-December 1955 and had recently weaned their calves. They were therefore comparable with the six original cows. They were introduced in order to increase the stocking rate and to provide larger numbers for studying liver copper concentrations in new-born calves and their dams. All calves born during the experiment were removed from the paddock after weaning at 7-9 months.

(3) *General Management.*—The animals were observed three times per week. Cattle tick, *Boophilus microplus,* populations were controlled on the cattle by regular spraying or dipping in 0·5 per cent. DDT mixtures. As a precaution against tick fever under these conditions of low tick infestation, cattle were inoculated at intervals of approximately three months with blood containing *Babesia argentina* and *B. bigemina.* The sheep and calves were drenched at intervals with phenothiazine to control internal parasites. Blowfly strikes were treated as they occurred, and in March 1956 all sheep were sprayed with dieldrin as a preventive measure during a blowfly wave. Calves and lambs were vaccinated with tetanus toxoid and blackleg vaccine 2-3 weeks before castration, dehorning or marking.

The sheep were shorn during March 1956, January 1957, September 1957 and October 1958. Crutching was not carried out during the experiment.

Both ewes and cows were "paddock mated". A raddled ram was introduced to the experimental paddock in 1958, when all ewes were mated. In 1956 and 1957, when only portion of the ewe flock was mated, a raddled ram was allowed to run with the group selected for mating. Ewes were examined three times per week for evidence of service. Mating, as indicated by raddling, took place during the following periods: April 20-28, 1956; May 22-31, 1957; and June 23 to July 18, 1958.

The cows were mated for a period of six weeks, dates of introduction of the bull being July 4, 1956, and February 25, 1958. In each year, mating was delayed until after weaning of the calves.

(4) *Body-weight.*—Body-weights of cows, calves and adult sheep were obtained on a cattle weighing scale with an accuracy of ± 1 lb.

(5) *Sampling and Analytical Methods.*—Liver samples were obtained at intervals of approximately three months by biopsy with the instruments described by Dick (1952). The procedure of Loosemore and Allcroft (1951) was used for cattle and that of Dick (1944) for adult sheep. An open laparotomy technique reported by Watson (1960) was used to obtain liver samples from new-born lambs. Liver samples were obtained from the new-born animals and their dams within 24 hr of parturition. The liver samples were analysed for copper by the method of Clare, Cunningham, and Perrin (1945), and the results have been expressed as dry matter (D.M.).

Blood samples were obtained with stainless steel needles from the external jugular vein on the same day as liver sampling. Analytical methods employed were as follows: blood copper, Clare, Cunningham, and Perrin (1945); blood inorganic phosphate, Moir (1954); and blood haemoglobin, Donaldson *et al.* (1951). The method of determination of packed cell volume was essentially that of Wintrobe (1947), using a relative centrifugal force of approximately 2067 *g*.

(6) *Duration of the Experiment.*—The portion of the experiment designed to compare liver and blood copper levels in sheep with those of cattle commenced in June 1955 and continued until June 1958. Both the sheep and cattle remained in the experimental area until the studies on liver copper levels of new-born lambs and calves were completed in March 1959.

III. RESULTS

(a) Liver and Blood Copper Levels in Sheep and Cattle

The liver and blood copper levels and body-weight of both sheep and cattle are presented in Figure 1. Except at the first three sampling periods, sheep had mean liver copper levels greater than 100 p.p.m. On only one occasion were levels below 60 p.p.m. With the exception of one sampling period, cattle had

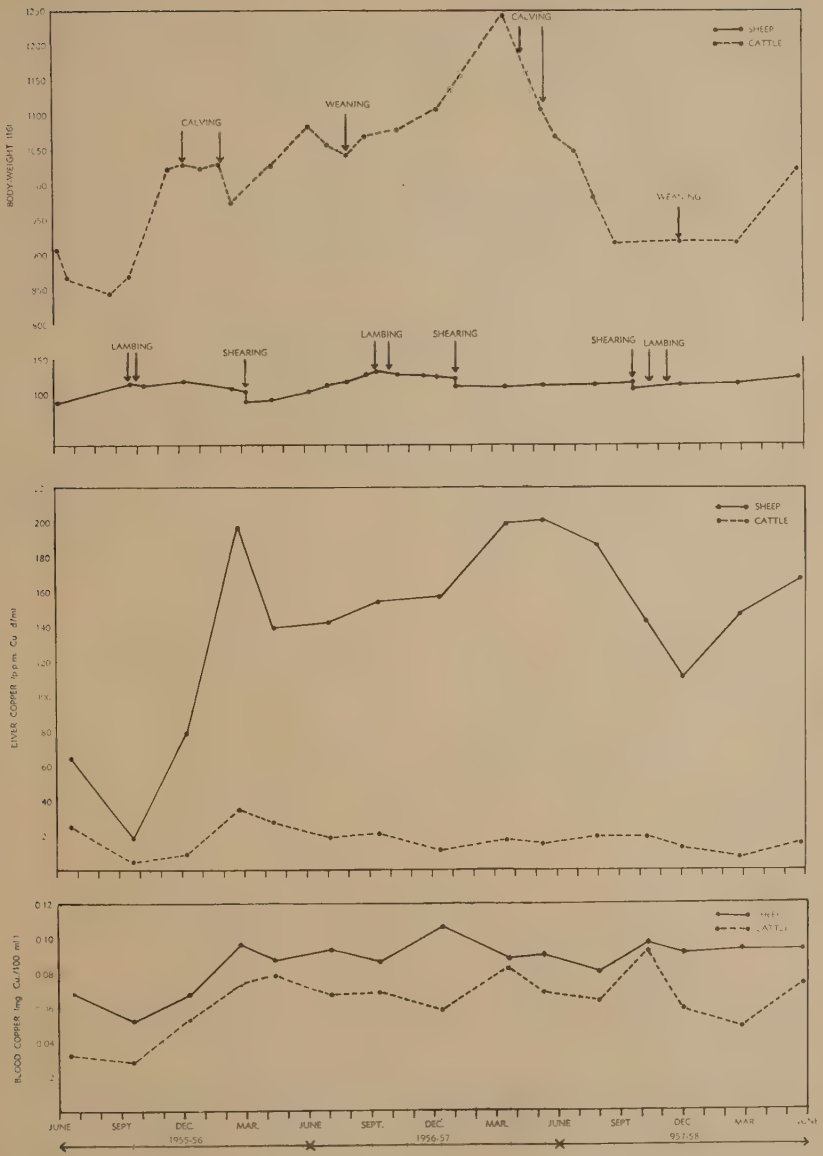

Fig. 1.—Mean changes in body-weight and in the concentration of copper in liver and blood of sheep and cattle grazing the same pasture.

mean liver copper concentrations which were less than 30 p.p.m. On three occasions the mean levels were less than 10 p.p.m. Cu. One of the six cows had liver copper reserves that were higher than those of all other cows for 13 of the 15 samplings. The mean liver copper concentration of this animal for all 15 samples was 41·3 p.p.m., compared with an average of the means for the other five of 12·2 p.p.m.

If the data on liver concentrations are considered for the periods July 1955 to June 1956, July 1956 to June 1957, and July 1957 to June 1958, there does not appear to be any marked consistent seasonal trend. In both sheep and cattle the maximum concentration in 1955-56 was recorded in late summer and the minimum level in spring. The data for 1956-57 show little seasonal variation. In 1957-58 there was a more marked seasonal variation than in the previous year and minimum values for sheep and cattle were found during the summer period.

Blood copper levels in sheep were below 0·08 mg Cu/100 ml for only the first three sampling times in 1955, whereas cattle had concentrations above this figure on only two occasions. From these data it would appear that the lowest levels in cattle were associated with the spring and summer periods, mean levels recorded in the three December samplings being 0·053, 0·058 and 0·058 mg Cu/100 ml. The lowest mean level recorded for cattle was 0·28 mg/100 ml in the spring of 1955.

In sheep, the relationship between mean blood and liver concentrations was $r = +0{\cdot}74$ ($P < 0{\cdot}01$). The lack of independence of successive measurements could have been an influence in this result. The comparable relationship between blood and liver copper concentration in cattle was not significant ($r = +0{\cdot}33$). Ignoring the lack of independence among successive measurements, the correlation between liver copper concentration for sheep and cattle was only $r = +0{\cdot}43$ ($P < 0{\cdot}1$). For mean blood copper levels, the correlation was $r = +0{\cdot}78$ ($P < 0{\cdot}01$).

(b) Effect of Pregnancy and Lactation on Liver and Blood Copper Concentrations in Sheep

The mean liver and blood copper concentrations of pregnant and non-pregnant ewes in 1956 and 1957 are shown in Table 1. Sampling times were approximately 3-monthly, the intervals being related to the pregnant group, viz., prior to mating, at mid-pregnancy, close to lambing, and during lactation. In 1956, the liver copper reserves increased during pregnancy and lactation, whereas during 1957 the levels decreased, but at a rate similar to that in the non-pregnant ewes. There was little change in blood copper concentrations during either year. There were no significant differences in either liver or blood copper concentrations between pregnant and non-pregnant ewes in either year. However, the difference between the blood copper levels of lactating and non-lactating ewes in 1956 was significant at the 5 per cent. level.

TABLE 1

EFFECT OF PREGNANCY AND LACTATION ON LIVER AND BLOOD COPPER CONCENTRATIONS IN SHEEP

—	Mating Period	Lambing Period	No. of Ewes	Mean Liver Copper Concentration (p.p.m. D.M.)				Mean Blood Copper Concentration (mg/100 ml)			
				13.iv.56	4.vii.56	14.ix.56	11.xii.56	13.iv.56	4.vii.56	14.ix.56	11.xii.56
Pregnant ewes ..	20.iv.56 to 5.v.56	10.ix.56 to 2.x.56	8	134	136	162	175	0·086	0·089	0·082	0·090
Non-pregnant ewes ..	..	..	7	147	148	148	152	0·087	0·087	0·087	0·116
Difference†	..	..	..	..	..	+24±13†	+30±17†	..	..	− 0·005 ± 0·009	−0·026 ± 0·011*
				10.v.57	29.vii.57	10.x 57	3.xii 57	10.v.57	29.vii.57	10.x.57	3.xii 57
Pregnant ewes ..	22.v.57 to 31.v.57	18.x.57 to 14.xi.57	8	165	153	103	79	0·094	0·086	0·091	0·085
Non-pregnant ewes ..	..	..	8	180	172	127	99	0·095	0·084	0·100	0·089
Difference†	..	..	..	..	..	−14±18†	−13±11†	..	..	− 0·009 ± 0·007	− 0·004 ± 0·006

* Difference significant at 5% level.
† Difference between means of pregnant and non-pregnant ewes adjusted for initial differences on 13.iv.56 for 1956 data and on 10.v.57 for 1957 data (mean and standard error)

TABLE 2

MEAN AND STANDARD ERRORS OF MEAN LIVER COPPER CONCENTRATION IN NEW-BORN CALVES AND LAMBS AND IN THEIR DAMS AT PARTURITION

CATTLE

Calving Period	Number		Mean Liver Copper Concentration (p.p.m. D.M.)		
	Cows	Calves	Cows at Calving	Calves at Birth	Difference between Calf and Cow
1957 (4.iv.57 to 16.v.57)	11	12†	17·1 ± 2·5	361 ± 33	344 ± 33***
1958 (6.xi.58 to 28.xi. 58)	8	8	9·8 ± 1·7	329 ± 58	319 ± 57***

SHEEP

Lambing Period	Number		Mean Liver Copper Concentration (p.p.m. D.M.)		
	Ewes	Lambs	Ewes at Lambing	Lambs at Birth	Difference between Lamb and Ewe
1957 (18.x.57 to 14.xi.57)	8	8	103·0 ± 12·3	157 ± 15	54 ± 15**
1958 (14.xi.58 to 23.xii. 58) ..	9‡	9	134 ± 12	239 ± 27	109 ± 21***
	6§	13	141 ± 15	262 ± 24	

† One cow gave birth to twins.
‡ Ewes giving birth to single lambs.
§ Ewes giving birth to twin or triplet lambs.
** Significant at 1% level.
*** Significant at 0·1% level.

(c) Liver Copper Concentrations in New-born Calves and Lambs

The mean liver copper concentrations in new-born calves and lambs, together with those of their dams, are shown in Table 2. In both species, the level in the new-born animals was significantly higher than in their dams, the difference in concentration between dam and offspring being more marked in cattle than in sheep.

There were no significant correlations between levels in the dams and their offspring for either sheep or cattle when the data for the two years were considered either separately or collectively.

(d) Liver Copper Concentrations in Calves during Early Growth

The body-weights and liver copper concentrations recorded at intervals for calves born in 1957 are shown in Table 3. Those for calves born in 1958 are shown in Table 4. In 1957, 10 of the 12 calves born alive completed the suckling period. One died five days after birth and one cow would not allow its calf to suckle. All six live calves born during 1958 completed the experiment.

In 1957, the calves were born in late autumn. Their mean growth rate in the 56 days from June 4 (mean age 47·3 days) to July 29 was 1·29 lb per head per day. The liver copper concentrations fell rapidly, but in general did not decline to levels comparable with those found in the cows until after the calves were three months of age.

The calves born in early summer in 1958 had a mean growth rate, in the 56 days from the following January 6 (mean age 51·8 days) to March 3, of 1·91 lb per head per day. Liver copper concentrations fell at a more rapid rate than in the previous year, levels having declined in three months to concentrations comparable with those of the cows.

Despite the rapid reduction in liver copper concentrations, these calves continued to grow at satisfactory rates.

(e) Liver Copper Concentrations in Lambs during Early Growth

In lambs born in 1957, the mean fall in liver copper concentration for the first four months of life was 13 p.p.m., whereas their dams over the same period showed a mean decline of 8 p.p.m. Lambs born in 1958 had much greater liver copper levels at birth (Table 4) and showed a mean fall in liver copper concentration for the first four months of life of 137 p.p.m., whereas the liver copper reserves in their dams increased by 46 p.p.m. over the same period.

TABLE 3

LIVER COPPER CONCENTRATION IN CALVES AND THEIR DAMS AND BODY-WEIGHT OF CALVES BORN IN 1957

Calf No.	Date of Birth	Liver Copper Concentration (p.p.m. D.M.) and Body-weight† (lb)								
		Dam	Calf at Birth	10.v.57	4.vi.57	1.viii.57	29.vii.57	26.viii.57	10.x.57	3.xi.57
1‡	4.iv.57	5	374	103	50	21	32	12	8	6
				100	*112*	*140*	*168*	*188*		*300*
2‡	4.iv.57		228	200	42	27	16	19	15	14
				113	*128*	*160*	*168*	*180*		*268*
3	9.iv.57	20	128	155	57	45	28	19	12	20
			66	*122*	*156*	*192*	*224*	*248*		*378*
4	15.iv.57	30	336	160	98	91	77	55	36	. . .
			80	*111*	*160*	*214*	*256*	*296*		*444*
5	17.iv.57	22	445	145	62	71	51	54	38	11
			52	*92*	*120*	*156*	*180*	*184*		*262*
6	18.iv.57	17	367	121	98	17	13	15	15	10
			60	*100*	*132*	*172*	*204*	*232*		*362*
7	27.iv.57	31	562	383	218	114	89	61	46	17
			69	*92*	*124*	*176*	*204*	*236*		*388*
8	9. v.57	12	336		136	76	56	40	22	10
			60	. . .	*144*	*196*	*232*	*268*		*408*
9	15. v.57	11	482	——	130	40	110	93	65	33
			60		*96*	*136*	*164*	*192*		*312*
10	16. v.57	9	338	——	190	116	98	59	40	20
			76		*120*	*162*	*206*	*232*		*382*
Mean		17·4	360							

† Body-weight in italics.
‡ Calves 1 and 2 were male twins.

. . . No liver sample obtained.
—— Calves not born.

TABLE 4

LIVER COPPER CONCENTRATION IN CALVES AND THEIR DAMS AND BODY-WEIGHT OF CALVES BORN IN 1958

Calf No.	Date of Birth	Liver Copper Concentration (p.p.m.) and Body-weight †(lb)					
		Dam	Calf at Birth	6.i.59	3.ii.59	3.iii.59	31.iii.59
1	6.xi.58	10	433	41	19	14	18
			68	*206*	*272*	*316*	*370*
2	9.xi.58	5	300	19	13	17	18
			66	*182*	*240*	*296*	*340*
3	14.xi.58	9	213	17	11	26	23
			56	*154*	*200*	*248*	*292*
4	17.xi.58	17	305	12	9	. . .	10
			56	*162*	*212*	*262*	*304*
5	17.xi.58	4	135	19	8	12	6
			56	*144*	*206*	*264*	*316*
6	28.xi.58	15	670	72	25	14	14
			70	*138*	*192*	*242*	*284*
Mean		10	343				

† Body-weight in italics.
. . . No liver sample.

(f) Blood Haemoglobin, Packed Cell Volume (P.C.V.) and Blood Inorganic Phosphate Levels in Experimental Animals

The blood haemoglobin, P.C.V. and inorganic phosphate levels for cattle at the 15 sampling periods varied from 12·3 to 14·9 g/100 ml, 31·4 to 44·0 per cent., and 3·1 to 5·3 mg/100 ml respectively. The range of these constituents for sheep were: haemoglobin 10·2 to 13·2 g/100 ml, P.C.V. 29·0 to 42·2 per cent., and blood inorganic phosphate 2·9 to 5·8 mg/100 ml.

IV. DISCUSSION

Studies during a period of three years indicate that in adult sheep grazing predominantly paspalum pastures on the Animal Husbandry Research Farm, Rocklea, the liver copper concentrations are in general greater than 100 p.p.m., whereas those in adult cattle are usually less than 30 p.p.m. There are at least three factors which could be responsible for these differences. Firstly, there is evidence of a species difference in the ability of cattle and sheep to store copper. Cunningham (1931, 1946), Bennetts and Chapman (1937), and Beck (1956) have recorded mean liver copper levels in "normal" adult sheep of 236, 599, 360 and 305 p.p.m. respectively, whereas Cunningham (1931, 1946) obtained levels of 77 p.p.m. and 200 p.p.m. respectively for adult cattle. Secondly, differences in the method of prehension by cattle and sheep may result in differential selection of pasture. It is therefore possible that the sheep were selecting a diet higher in copper than that obtained by the cattle. Thirdly, it is possible that cattle and sheep are not affected similarly by factors interfering with copper metabolism. In the year preceding these studies, copper levels were determined at monthly intervals on the predominant pasture species on this property. Levels ranged from 6·5 to 8·8 p.p.m. Cu on a dry-matter basis. A low copper status in grazing cattle suggests some factor or factors which interfere with the availability of this copper to cattle. Harvey, Ryley, Beames, and O'Bryan (1961) showed that molybdenum in the presence of high levels of inorganic sulphate exerted a similar effect on the storage of copper in livers of both sheep and cattle, but that this factor was unlikely to be responsible for the low levels of liver copper found in cattle at Rocklea.

The generally low concentration of copper in the liver and blood of cattle did not appear to result in anaemia, clinical symptoms of copper deficiency, or poor growth of suckling calves. These findings are in agreement with those reported by Sutherland (1956) in which no response in growth rate was recorded following parenteral copper therapy of cattle on this property.

The lack of correlation between blood and liver copper concentrations in the cattle is in agreement with the results obtained by Loosemore and Allcroft (1951). However, because of the small number of experimental animals in our studies, only a very strong relationship could be expected to be statistically significant.

In our experiment, pregnancy did not affect liver or blood copper concentrations in ewes. This is contrary to published data for pregnant cows. van der Grift (1955) found that the amount of copper in the liver decreased during the last four months of pregnancy. Allcroft and Uvarov (1959) stated that the copper concentration in the livers of pregnant cows falls during gestation. In the latter case, the small number of animals and the fact that comparisons were made between different animals biopsied at varying intervals before parturition may have influenced the findings.

There is general agreement that, in the bovine, new-born animals have higher liver copper concentrations than adults. Cunningham (1931, 1946), on data from slaughtered animals, reported higher liver copper levels in new-born calves than in adult cows. In a herd in which copper deficiency occurred, Allcroft and Uvarov (1959) found higher concentrations in calves slaughtered within four days of birth than in their untreated or treated dams. Pryor (1960) found that copper concentrations in livers of bovine foetuses were significantly higher than in their dams. Our findings with new-born calves are in agreement with these published data.

With sheep our results show liver copper concentrations in new-born lambs significantly higher than those of their dams at parturition. This would appear to be contrary to the findings of Cunningham (1931, 1946). However, his results were not obtained in a direct comparison of the copper levels in livers of new-born lambs with those of their dams.

The rapid decrease in liver copper concentration in growing calves is in agreement with the findings of Cunningham (1946). The marked fall in liver copper concentration suggests that total liver reserves declined, although it was not possible to determine changes in total dry-matter weight of liver in our studies.

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EFFECT OF LOWERING THE MOISTURE CONTENT OF CHEDDAR CHEESE ON QUALITY AND YIELD

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SUMMARY

Cheese was manufactured experimentally on eight consecutive days in each month of a year at a selected factory. A manufacturing technique designed to produce cheese of a lowered moisture content was employed on alternate days in each period, while a normal technique was employed on the other days.

A difference of 1·73 per cent. in the average moisture content in the fat-free-substance of the two types of cheese was attained. The low-moisture cheese attained an average total grade points score 0·67 pt. higher than that attained by the normal cheese, and it also scored significantly higher average points for flavour, body and colour.

The results obtained failed to clearly indicate the lower level of the percentage of moisture in the fat-free-substance of the cheese below which no further improvement in grade could be gained. Some observations are made in regard to the possible relationship between this finding and the cheese-grading system.

Fluctuations in the level of moisture content in the fat-free-substance of the cheese and in the differences between the two types of cheese in regard to the moisture content, and a weakened relationship between grade points scored and moisture content when considered over the whole period, suggested that the optimum level of moisture content in the fat-free-substance insofar as grade is concerned might be a fluctuating rather than a fixed one.

The lowering of the moisture content of the cheese caused a loss of yield equal to 1.72 per cent. of production. The possible monetary loss involved is considered in relation to a varying price level for cheese and the extent to which differential payments according to cheese grade might recompense for the loss.

I. INTRODUCTION

Most practical cheesemakers agree on the necessity to reduce the moisture content of cheddar cheesecurd when the milk used is of poor quality, in order to increase the chances of producing cheese of acceptable quality. Authors of text-books on cheesemaking commonly infer that an association between the moisture content of cheese and its quality does exist. Thus Sammis (1942, p. 75) stated "... it is to be expected that high moisture cheese from unclean or over ripe milk will develop unclean or acid flavours sooner and to a greater extent than if the cheese has been made drier". Van Slyke and Price (1952, pp. 38-9) stated: "Moisture content has a decided influence on many properties of cheese such as acidity, flavour, body, texture and speed of ripening. These properties differ widely within each variety of cheese and for different types of cheese. Properties induced by low moisture are preferred by some consumers while buyers in other markets

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want cheese with high moisture. It is obvious that no single moisture standard can indicate a quality ideal for every market". Wilster (1955, p. 212) stated: "The water in the fat-free portion of cheese will range from 52 to 58 per cent. in cheese from different factories. In freshly made cheese the ideal percentage is approximately 55 to 56 per cent and in one month old cheese it is from 53 to 54 per cent. Further research under accurately controlled conditions is necessary in order to show the desired percentage. For cheese which is to be cured for about a year a low percentage of moisture in the fat-free portion of cheese is undoubtedly desirable."

Experimental work designed to investigate the relationship, if any, between the moisture content of cheese and its grade has been very limited. Sammis and Germaine (1929) examined the composition and quality of a number of experimental cheeses and showed among other things that there was a lowering of quality score of the cheese corresponding with an increase in the proportion of moisture to casein.

In a report to the Australian Society of Dairy Technology, MacDonald *et al.* (1957) stated that the results from some Australian experimental cheese manufacturing showed an improvement in score for total grade score, flavour, body and colour, but not texture, as the percentage of moisture in the fat-free-substance of the cheese decreased.

The work reported here was undertaken with a view to assessing the extent to which a lowering in the percentage of moisture in the fat-free-substance of cheddar cheese could improve the quality and also to examine some of the economic aspects of such a practice.

II. METHODS

(i) *General.*—A factory with a daily milk intake ranging from 500 to 1,500 gal. during the year was selected. Experimental cheese manufacture was conducted for eight consecutive manufacturing days in each month of a complete year. On these days the whole of the factory's milk intake was manufactured into cheese, using techniques designed to produce a lowered moisture content on certain days and a normal moisture content on the alternate days, but at the same time endeavouring to attain as high a grade score as possible on all days By utilizing the whole of the factory's intake of milk in this way, it was hoped to attain reasonable uniformity in the composition and cheesemaking characteristics of the milk being used for the manufacture of the two types of cheese.

The yields of cheese obtained by the different methods were recorded and the loss of weight (shrinkage) of the two types of cheese was assessed for the 10 days during which they were stored at the factory. The cheese was graded and analysed at 2-3 weeks of age.

(ii) *Manufacture of Cheese.*—In general, the methods employed for the manufacturing of cheese were those described by Rice and Morris (1954).

However, preliminary investigational work was carried out to determine a satisfactory technique for producing cheese with a lowered moisture content. It was found that the addition of calcium chloride to the milk at the rate of 3 oz per 100 gal produced a firm clot which allowed extra cutting of the coagulum. The smaller particles thus produced could be expected to lose moisture more rapidly, at least in the early stages of manufacture (Whitehead and Harkness 1954). (The possibility of the addition of calcium chloride to the milk having effects other than promoting rapid coagulation with rennet necessitated the use of this substance on the alternate, i.e. "normal", days as well.) A slightly higher cooking temperature of 101°F was employed and the whey was run off at a slightly higher acidity. Dry-stirring of the curd was carried out when the whey was drained off and small curd blocks were cut for cheddaring.

A lower salting rate was employed. It was the intention to reduce the moisture content of the curd before the salting stage was reached so that only sufficient salt to give a normal concentration of salt in the moisture of the cheese would be required. By keeping the concentration of salt in the moisture at the same level for both types of cheese, the possibility of differences in cheese quality being caused by differences in salt content was eliminated.

The main features of the two cheese manufacturing procedures employed are set out hereunder:—

Treatment	Low-moisture Cheese	Normal Cheese
Calcium chloride	3 oz per 100 gal milk	3 oz. per 100 gal milk
Starter	Same percentage both types of cheese	Same percentage both types of cheese
Cutting	Extra cut given with vertical knife	Normal cutting
Cooking	Cooked to 101°F in 35-40 min	Cooked to 98°F in 35-40 min
Running	Run at a slightly higher than normal acidity	Run at a normal acidity
Drying	Given from 1-4 dry stirs	Not given any dry stirs
Cheddaring	Cut small and turned every 10 min	Cut large and turned every 15 min
Milling	Milled at 1½ hr from drying	Milled at 1½ hr from drying
Salting	2½% salt at 2½ hr from drying	3-3½% salt at 2½ hr from drying

In order to obviate any effect of the starter cultures used, the alternation of the two methods of cheese manufacturing was reversed after the first four days of the 8-day periods. Since the factory was using a 4-day rotation of starters, this allowed each day's starters to be used in the manufacture of both types of cheese.

(iii) *Assessing Cheese Yield and Cheese Shrinkage.*—The weight of milk used in the manufacture of cheese each day was recorded. The cheeses produced were weighed when removed from the presses and again at 10 days of age just before they were transported from the factory. From the figures thus obtained it was possible to calculate the weight of green cheese produced for each 100 lb milk used and also the amount of weight lost by the cheese during the storage period.

A composite sample of the milks used for each type of cheese during the 8-day periods was analysed to determine the butterfat and the casein contents. From the yield of green cheese per 100 lb milk and the butterfat test of the milk, it was possible to calculate the yield of cheese per lb butterfat used in cheese manufacturing.

The casein content of the milk employed in the manufacture of the two types of cheese was recorded in order to take account of the effect on the yield of cheese which differences in the composition of the two lots of milk might have. However, no significant differences in either fat or casein content occurred between the two composite samples of milk during any of the 8-day periods of the experiment and therefore it was possible to make a direct comparison of the cheese yields obtained.

(iv) *Grading, Sampling and Analysing the Cheese.*—The 80 lb cheeses produced were submitted to the State Dairy Produce Inspector for official grading and allotment of points as normally conducted in Queensland and the Commonwealth of Australia. Under this system, the maximum points allotted are 50 for flavour, 30 for body and texture and 20 for condition, which includes colour. In application, this system does not result in a very wide variation in the points scored by different cheeses for body and texture, and of course does not provide any distinction between these two attributes in the points allotted. However, it is usual for the actual points allotted to be supplemented by a brief written description of any defects. It was considered necessary to translate these written descriptions into a scale of points which would adequately reflect any differences between the qualities of various cheeses, and a special key to effect this translation was adopted for each of the three attributes, body, texture and colour. The keys used are shown hereunder:—

Comments on Body	Points Allotted
Firm, good, meaty	5
Fairly firm, fairly good, shade weak, inclined weak, very slightly weak, firm inclined mealy	4
Slightly weak, firm but slightly mealy, firm but slightly corky	3
Weak, pasty, corky, mealy	2
Very weak, very pasty, very corky, very mealy	1

Comments on Texture	Points Allotted
Close	5
Very slightly open	4
Slightly open	3
Open	2
Very open	1

Comments on Colour	Points Allotted
Good, bright	5
Fairly good, fairly bright, slightly wavy, slightly uneven, very slightly dull	4
Slightly dull, slightly bleached	3
Dull, bleached	2
Very dull, very bleached	1

At the same time as the cheeses were graded, which was at 2-3 weeks of age, samples were taken for analysis. The person grading the cheese was unaware of the composition or intended nature of the cheese, i.e. whether it was normal or low-moisture, and was thus free from any preconceived judgments in relation to it. In order to eliminate the possible effect of sampling at slightly different ages, about 1 in. of the rind end of the cheese plugs was rejected from the sample in each case. It was considered that this practice would adequately safeguard the samples against the effect of variations in the degree of dehydration of the outside layers of the cheese (Scott 1954).

The moisture content was obtained by drying samples to constant weight in a vacuum oven (25-27 in. vacuum) maintained at the temperature of boiling water. Butterfat content was determined by the Babcock test.

III. RESULTS

(a) General

A total of 174 vats of cheese was manufactured in the course of the experiment, but in the consideration of the results all vats of cheese which showed any abnormality in manufacture not related to the particular method of manufacture, such as starter slowness, or were in any other way in doubt as regards normality, were excluded. When this abnormality affected one vat of a pair, both were excluded. In some cases it was not possible to obtain analyses or grades of the vats of cheese manufactured and a number of vats were thus excluded from consideration in comparisons of composition with grade scores. The fate of the batches of cheese used in compiling the various tables of results is shown in Table 7.

(b) Quality of Cheese

A comparison of the average moisture content and average grade points scored by the two classes of cheese produced during the experiment is shown in Tables 1 and 2.

TABLE 1

COMPARISON OF MOISTURE CONTENTS OF NORMAL AND LOW-MOISTURE CHEESE

Type of Cheese	No. of Vats	Average Moisture (%)	Average Moisture in Fat-free-substance (%)
Low-moisture	60	34·84	52·26
Normal	60	36·17	53·99

TABLE 2

COMPARISON OF GRADE POINTS SCORED BY NORMAL AND LOW-MOISTURE CHEESE

Type of Cheese	No. of Vats	Average Normal Grade Points Scored		Average Special Grade Points Scored		
		Total	Flavour	Body	Texture	Colour
Low-moisture	75	91·02	41·49	4·28	3·41	4·35
Normal	75	90·35	40·95	3·87	3·28	4·05

TABLE 3

SPREAD OF DIFFERENCES IN POINTS SCORE FOR NORMAL AND LOW-MOISTURE CHEESE
(Low-moisture score minus Normal score)

—	Points Difference																	Total No. of Pairs	Average Points Difference
	−3½	−3	−2½	−2	−1½	−1	−½	0	½	1	1½	2	2½	3	3½	4	4½	5	
Total grade—No. of Pairs ..	1	0	2	3	4	7	2	8	9	15	8	6	2	4	0	2	1	1	75	0·66 ± 0·19*
Flavour—No. of Pairs	..	..	1	1	3	7	8	9	13	14	8	6	1	3	0	1	..	..	75	0·53 ± 0·14*
Body—No. of Pairs	..	..	..	1	..	14	..	21	..	32	..	6	..	1	..	..	..	..	75	0·41 ± 0·11*
Texture—No. of Pairs	..	1	..	5	..	8	..	39	..	13	..	9	..	0	..	..	..	..	75	0·13 ± 0·12
Colour—No. of Pairs	..	..	..	1	..	12	..	31	..	25	..	6	..	..	..	..	..	..	75	0·31 ± 0·10*

* Significant at 1% level.

These tables show that a difference of 1·73 per cent. in the average moisture content in the fat-free-substance of the two types of cheese was attained. The maximum possible error in a determination of the percentage moisture in the fat-free-substance of cheese has been stated by Whitehead (1948) to be ± 1·15 per cent. under the methods of sampling and analysis employed by him. The maximum error in determining the percentage of moisture in the fat-free-substance of cheeses analysed in this work could not be expected to be any greater than this and therefore would be considerably less than the average difference in percentage of moisture in the fat-free-substance attained.

There was a difference in grade points scored in favour of the low-moisture cheese in the case of total grade, flavour, body, texture and colour. The difference was greatest for total grade and least for texture.

The spread of differences in the various grade points scored is shown in Table 3. This method of presentation shows the relative frequency with which the various differences resulted. In the case of total grade, the low-moisture cheese scored better than the normal cheese in 48 pairings, was equal in 8 pairings and was worse in 19 pairings. The low-moisture cheese scored better for flavour in 46 pairings, was equal in 9 pairings and was worse in 20 pairings. The respective figures in relation to body score are 39, 21 and 15; for texture score they are 22, 39 and 14; and for colour score they are 31, 31 and 13.

In Table 4, the vats of both types of cheese produced during the experiment are considered independently of their intended nature, i.e. whether normal or low-moisture, and a comparison is made of the average moisture content of the fat-free-substance of the vats of cheese scoring within certain divisions of the points scale for the various properties considered. In Table 5, a comparison is made on a similar basis but in this case the points scores of the batches of cheese are averaged for certain divisions of the range of moisture content in the fat-free-substance.

(c) Yield of Cheese

The average yields of cheese obtained are shown in Table 6 together with the average losses of weight (shrinkage) during the 10 days the cheese was held at the factory prior to disposal. A lowering of the yield of cheese occurred in the case of the low-moisture vats, but this was slightly compensated for by the reduced loss of weight incurred with this type of cheese during the time it was held at the factory. The gross lowering of yield of cheese found was 0·19 lb per 100 lb milk, or 0·06 lb cheese per lb butterfat, while the figures for the net loss were 0·17 lb and 0·05 lb respectively.

The calculated loss of yield incurred by reducing the moisture content of cheese from 36·17 to 34·84 per cent., when the initial yield is 9·96 lb per 100 lb milk, is 0·20 lb per 100 lb milk. The actual loss found in these trials

TABLE 4

PERCENTAGES OF MOISTURE IN THE FAT-FREE-SUBSTANCE OF VATS OF CHEESE WITHIN DIVISIONS OF POINTS SCORED FOR VARIOUS PROPERTIES

(a) Total Grade

Divisions of Points	Over 92·5	92·0–92·5	91·0–91·5	90·0–90·5	89·0–89·5	88·0–88·5	Below 88·0
No. of vats	4	17	46	42	9	3	2
Average moisture	52·3	53·0	53·1	53·3	53·8	54·3	54·5
Range of moisture	49·5–54·9	50·3–56·9	49·9–57·1	49·6–57·7	52·5–55·8	53·6–55·2	53·9–55·1

(b) Flavour

Divisions of Points	Over 42·5	42·5	42·0	41·5	41·0	40·5	40·0	39·0	Below 39·0
No. of vats	4	6	21	36	34	9	8	2	3
Average moisture ..	52·3	52·7	53·1	53·2	52·9	54·0	53·9	54·4	54·3
Range of moisture ..	49·5–54·9	50·3–56·9	50·0–56·5	49·9–57·7	49·6–55·9	52·8–56·0	52·5–55·8	53·6–55·2	53·9–55·1

(c) Body

Divisions of Points	5	4	3	2	1
No. of vats	33	68	22	..	..
Average moisture	52·7	53·4	53·4	..	..
Range of moisture ..	49·5–56·9	49·6–57·7	50·7–55·8	..	..

(d) Texture

Divisions of Points	5	4	3	2	1
No. of vats	14	21	81	7	..
Average moisture	53·6	52·4	53·2	54·3	..
Range of moisture ..	50·5–56·9	49·5–56·0	49·9–57·7	52·8–55·3	..

(e) Colour

Divisions of Points	5	4	3	2	1
No. of vats	36	77	10	..	..
Average moisture	52·5	53·5	53·8	..	..
Range of moisture ..	49·5–56·9	49·9–57·7	52·0–55·1	..	..

CORRELATION COEFFICIENTS

Total grade score	·1225**
Flavour score	·1039**
Body score	·0592
Texture score	·0318
Colour score	·0853

** Significant at 5% level.

TABLE 5

POINTS SCORED FOR VARIOUS PROPERTIES OF VATS OF CHEESE WITHIN DIVISIONS OF PERCENTAGE OF MOISTURE IN THE FAT-FREE-SUBSTANCE

	Divisions of Moisture Percentage						
	Over 55·0	54·0–54·9	53·0–53·9	52·0–52·9	51·0–51·9	50·0–50·9	Below 50·0
Total Grade—							
No. of vats	17	27	27	23	15	11	3
Average points score	90·4	90·6	90·5	90·8	91·0	91·4	91·5
Range of score	87·0–92·5	88·0–93·0	87·0–92·0	89·0–93·0	90·0–93·0	90·0–92·5	90·5–93·0
Flavour—							
No. of vats	17	27	27	23	15	11	3
Average points score	41·0	41·1	41·1	41·4	41·5	41·7	41·8
Range of score	38·5–42·5	38·5–43·0	38·5–42·5	40·0–43·0	41·0–43·0	41·0–42·5	41·0–43·0
Body—							
No. of vats	17	27	27	23	15	11	3
Average points score	4·0	4·0	4·1	4·0	4·3	4·4	4·3
Range of score	3·0–5·0	3·0–5·0	3·0–5·0	3·0–5·0	3·0–5·0	3·0–5·0	4·0–5·0
Texture—							
No. of vats	17	27	27	23	15	11	3
Average points score	3·4	3·3	3·3	3·3	3·3	3·7	3·7
Range of score	2·0–5·0	2·0–5·0	2·0–5·0	2·0–5·0	3·0–5·0	3·0–5·0	3·0–4·0
Colour—							
No. of vats	17	27	27	23	15	11	3
Average points score	4·1	4·1	4·2	4·1	4·3	4·7	4·7
Range of score	3·0–5·0	3·0–5·0	3·0–5·0	3·0–5·0	4·0–5·0	4·0–5·0	4·0–5·0

is not greater than this, and it therefore seems a safe assumption that the manufacturing methods employed in reducing the moisture content did not cause any increased loss of cheese-yielding constituents other than moisture.

TABLE 6

COMPARISON OF CHEESE YIELDS AND SHRINKAGES

Type of Cheese	Average Green Cheese Yield		Average Shrinkage (%)	Calculated Average Yield of 10-day-old Cheese	
	Per 100 lb Milk (lb)	Per lb Butterfat (lb)		Per 100 lb Milk (lb)	Per lb Butterfat (lb)
Normal	9·96	2·74	0·99	9·86	2·71
Low-moisture ..	9·77	2·68	0·82	9·69	2·66

TABLE 7

DISSECTION OF REJECTIONS FROM TABLES OF RESULTS

Reasons for Rejection	Number of Vats Rejected					
	Table 1		Tables 2 and 3		Tables 4 and 5	
	Normal	Low-moisture	Normal	Low-moisture	Normal	Low-moisture
Abnormality—						
In normal						
In low-moisture ..	4	4	4	4		2
In both						
Grade not obtained—						
For normal						
For low-moisture ..						
For both			8	8	8	8
Analysis not obtained—						
For normal	1	1			1	
For low-moisture ..						
For both	22	22			16	16

IV. DISCUSSION

(a) Quality of Cheese

The improvement shown in the grading quality of cheese resulting from a lowering of its moisture content is apparently composed of an improvement in all the main attributes with the exception of texture, where the difference is so small as to be not significant. While the improvement gained in the average grade is not great (0·67 grade points), it should be noted that this was achieved when the average moisture content of the normal cheese was only 36·17 per cent. and when this cheese was already achieving a fair average grade of 90·35 pt. Had the normal cheese been of a higher moisture content, the differences attained between the two types of manufacture could have been greater.

The extent to which the difference in grade would be reflected in a difference in the quality of the matured cheese was not assessed owing to difficulties associated with the storing and maturing of large quantities of cheese and also

because it was felt that the task of the cheese grader is partly to endeavour to predict the mature quality of the cheese and the grade he assigns it should therefore reflect this. While the actual quality of the cheese when matured is extremely important in the long-term interests of the industry as a whole, the more immediate concern, especially to the individual factory, is the grade initially assigned to the cheese.

It seems logical to expect that there is a limit in the reduction of the moisture content of cheddar cheese below which the grade not only fails to be improved but is actually lowered. For example, it is recognized that an excessively dry cheese has a hard and corky body which detracts from its quality and incurs a loss of grade points. However, an examination of the results obtained in this work, as set out in Tables 6 and 7, does not allow a decision to be made in regard to just what content of moisture in the fat-free-substance of cheddar cheese can be regarded as the lower limit beyond which any further reduction does not improve the quality. In these results it is observed that some improvement in score, except in the case of body, is still evident at the lowest average level of moisture content encountered. Since there is a tendency for very dry cheese to be almost completely lacking in any flavour, the question arises as to whether these results indicate an excessive negativity in the cheese grading system where flavour judgments are concerned, especially in view of the dominant role which flavour judgment plays in determining the grade of the cheese.

It is possible that if the cheese lost points because of a lack of any flavour, just as it loses points for the presence of abnormal flavours, the results could have been more clearly indicative of the minimum level of moisture in the fat-free-substance that is desirable.

The relationship between moisture content and grade is not so apparent from Tables 6 and 7; this could be expected from the results in Tables 4 and 5, where paired vats are compared. Since the experiment was carried on over a long period, it could be argued that a seasonal influence might have interfered with the results included in these tables. It is possible that the most suitable moisture content in the fat-free-substance at one time of the year is not the most suitable at another time. Such a shift in the optimum moisture content during the year would reduce the apparent relationship between moisture content and grade by spreading the best grades over a wider range of moisture content.

The average moisture content of the cheese resulting from the two methods of manufacture fluctuated throughout the experiment, but the better average grade for the low-moisture cheese indicates that its fluctuating level of moisture content was closer to the also fluctuating optimum level. The range in the monthly average moisture content in the fat-free-substance of the low-moisture cheeses was 49·9 to 54·3 per cent., while the corresponding range for the normal cheese was 52·4 to 56·2 per cent.

It is of interest to note that, although there was no marked change at any time in the methods used to gain a reduction in the moisture content of the cheese, the difference between the monthly average moisture content in the fat-free-substance for the two types of cheese varied from 0·7 to 2·7 per cent. It is a matter of conjecture as to why a set method of manufacture should be much more effective in reducing the moisture content of the fat-free-substance of the cheese at some times than it is at others. The fat and casein contents of the milk used in cheesemaking during this experiment did not appear to have any consistent influence on the extent of moisture reduction achieved by the low-moisture technique of manufacture.

(b) Yield of Cheese

The yield of cheese obtainable from a certain quantity of milk is an important economic factor in the cheese industry and one which can be measured. The better grading quality of the low-moisture cheese produced during this experiment must be weighed against the loss of cheese yield which occurred. The net reduction of 0·17 lb in the yield of cheese per 100 lb milk represents a loss of 1·72 per cent. of production. The monetary value of this varies according to the price obtainable for cheese, and is set out hereunder for various price levels.

Price of Cheese (per cwt)	Value of Loss of 1·72 per cent. Yield
s.	*s. d.*
150	2 7
170	2 11
190	3 3
210	3 7
230	3 11
250	4 4
270	4 8
290	5 0
310	5 4

It can be seen that the cost by way of lost cheese yield as a result of the low-moisture method of manufacture varies from 2s. 7d. to 5s. 4d. per cwt cheese according to the price level. With a system of differential payments for cheese according to its grade, there could be some monetary compensation by way of a higher price for the better grade of cheese. The price differentials at present imposed by the Australian Dairy Produce Board are as follows:—

Cheese Grade (pt.)	Difference from Basic Price (per cwt)
	s. d.
94 and over	+ 1 2
93	–
92	– 1 2
91	– 2 4
90	– 4 8
88-89	– 9 4
86-87	–17 6
83-85	–50 2

From this it can be seen that the particular grading results achieved in this experiment, viz. an increase in average grade from 90·35 to 91·02 pt., would bring about an increased monetary return of 2s. 4d. per cwt cheese. Therefore the cost of the lost yield would be recouped only if the price for cheese was as low as 135s. per cwt.

If the corresponding increase in grade was brought about from a lower normal level than that experienced in this experiment, the recoupment from the increased differential would be greater. Thus an increase in average grade from 89·35 to 90·02 pt. would recoup the cost of the lost yield up to a price level of 270s. per cwt.

The influence which quality itself has on the economics of the industry as a whole is difficult, if not impossible, to measure. While the maintenance of a high standard of quality and the establishing of a good reputation for the produce in world markets must be expected to have some ultimate effect on the economic security of the industry, the assessment of the value to be placed on such intangibles is quite outside the nature and scope of this work.

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RELATIONSHIP OF SALT CONTENT AND WEED TAINT PERCEPTION IN BUTTER

By W. D. Mitchell, B.Agr.Sc.*

SUMMARY

It was demonstrated in laboratory and commercial trials that the addition of salt to unsalted butter increased the organoleptic perception of inherent weed-tainting substances in butter.

When brine concentrations below 5.0 per cent. were obtained in unsalted butter which graded 93 and 92 pt. initially, insignificant changes in quality were evident. However, at levels of normal salting, i.e. a brine concentration of 9.60 per cent. representing a 1.52 per cent. salt content in a 15.80 per cent. moisture, a loss of one grade point occurred. When brine concentration was increased to a level of approximately 14.0 per cent., quality deteriorated by a further ½ pt. This degree of quality deterioration at higher salt concentrations was constant for butters of differing initial quality.

I. INTRODUCTION

The influence of salt on the flavour of foods is well established in practice. "Saltiness" is accepted as one of the four basic sensations of taste. The mechanism of salt action in the determination of flavour, however, is not clearly established, largely because the flavour of a food is a composite of the senses of taste, smell, sight and touch and as yet knowledge of the chemistry of flavouring substances is incomplete.

McDowall (1953) reported that it is factory practice in Australia and New Zealand to vary the level of salt content of butter between seasons. In spring months in particular, levels are reduced to as low as 1·1 or 1·2 per cent. to minimize the intensity of feedy off-flavours, mainly clover taints, although any endeavour to maintain consistently low concentrations is influenced by over-run considerations. Analyses of butters from Queensland factories revealed the mean salt content to be 1·41 per cent. in 1958-59 and 1·40 per cent. in 1959-60. The average salt level for the individual factories, however, ranged from 1·04 to 1·81 per cent. and 0·94 to 1·85 per cent. for the respective years. It has also been noted that butters entered for competitions have a markedly reduced salt content, and generally the butter awarded the highest points contains the lower salt concentrations. A second revealing feature regarding the relationship of salt to the flavour of butter is the increased quality of high quality butter which is manufactured when shipments of unsalted butter are required for export markets.

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The incidence of weed off-flavours in Queensland butter is most severe and highly seasonal in nature (Mitchell 1960), and it has been an accepted advisory recommendation to manufacturers to decrease the salt content during the critical period (Pitceathly 1960). It is also during this period of severe weed off-flavours that consumer complaints concerning unsatisfactory flavour in butter are more frequent.

To ascertain the influence of salt on the perception of weed flavours in butter, and to compare the effect of different levels of salt on the intensity of these off-flavours, a series of laboratory and commercial factory churnings were manufactured during the winter-spring period of 1960.

II. METHODS

(1) *Salting.*—As the normal level of salt content of butter approximated 1·5 per cent., trial churnings in each series were prepared at levels of 0·7, 1·0 and 1·5 per cent., representing very low, low and normal content respectively. Samples of unsalted butter were also prepared in laboratory trials. Plasticized pats containing approximately 2·2 per cent. salt were prepared from commercial bulk churnings.

(2) *Analytical.*—In all instances, only raw cream which had been graded and processed as choice quality was used for butter manufacture. This precaution was necessary to eliminate any masking effect on weed flavours by off-flavours associated with low quality creams. Moisture and salt content of samples were determined by the Kohman (1919) method and in the case of factory samples moisture distribution was determined by the Muller (1952) microscopic technique.

Isolated samples of plasticized pats were analysed for composition. As all butter supplies to this plant are standardized on laboratory analysis, the results obtained were considered typical of all butter examined.

(3) *Laboratory Manufacture.*—Laboratory pats were prepared from washed butter grain collected on churning day from a nearby factory. Separate portions were blended with a measured quantity of granular salt and/or moisture in a household electric mixer to provide both the unsalted sample and the butters with the three levels of salt content. Pats of approximately 1 lb were manufactured.

In most of the trials, samples of the factory manufacture from the original butter grain were also collected for comparative analyses and grading. This was done to check the accuracy of manufacturing techniques of laboratory churnings, as some difficulty was experienced in ensuring that laboratory samples were free from traces of mottle defect.

(4) *Commercial Manufacture.*—Trial churnings under commercial conditions were manufactured in the Esk, Proston and Chinchilla factories, each of which is situated in a district adversely affected by weed growth. Because of a shortage of sufficient supplies of choice quality cream for comparative churnings, only a small number of samples were prepared at Proston and Chinchilla factories.

Experimental cream for churning was processed in bulk and divided into three separate churnings for manufacture. As it is not normal procedure in Queensland factories to analyse butter for salt content, the method of salting followed regular practice in which a weighed quantity based on the estimated loading is added. This procedure did result in slight variations from the desideratum in the final salt content of comparative churnings.

Bulk butter from each factory was forwarded to Brisbane, where it was prepared by the Abel vacuum process (Gunnis 1959) for distribution on the local market. The salt content of these plasticized pats approximated 2·2 per cent. and moisture content was 15·8 per cent. Samples were compared for quality with the initial bulk supply.

(5) *Grading.*—All samples were graded within 4–7 days after manufacture by a panel of two or three qualified graders. Grading comments were confined to a description of weed off-flavours, and differences in quality of the order of ¼ pt. were recorded.

III. RESULTS

As the salt added to butter becomes distributed finally in the form of brine, grading results in this investigation were related to brine concentration of the respective butters. No determination of brine concentration was undertaken, this value being calculated from the salt and moisture analyses of each sample. Assuming that the salt and moisture are evenly distributed throughout the butter, salt levels of 0·7, 1·0, 1·5, and 2·2 per cent. in a butter of 15·8 per cent. moisture correspond to brine concentrations of 4·43, 6·33, 9·49 and 13·92 per cent. respectively.

(a) Salted v Unsalted

The results of 19 laboratory comparisons of unsalted and normal salted churnings are listed in Table 1. Mean brine concentration of the normal churnings was 9·60 per cent. Grade score for salted churnings fell from 92·71 to 91·78, i.e. 0·93 pt. lower than that obtained for the unsalted butter from identical cream.

TABLE 1

MEAN GRADE SCORE OF UNSALTED AND SALTED ("NORMAL" LEVEL) BUTTERS

No. of Churnings	Unsalted		Salted			
	Grade Score (pt.)		Grade Score (pt.)		Brine Concentration (%)	
	Range	Mean	Range	Mean	Range	Mean
19	92–93	92·71	91–92·75	91·78	8·82–10·82	9·60

TABLE 2

MEAN GRADE SCORE OF BUTTER SALTED AT DIFFERENT LEVELS (LABORATORY MANUFACTURE)

Brine Concentration Range (%)	Unsalted Grade (93 pt.)			Unsalted Grade (92½ pt.)			Unsalted Grade (92 pt.)		
	Number of Churnings	Mean Brine Concentration (%)	Mean Grade Score (pt.)	Number of Churnings	Mean Brine Concentration (%)	Mean Grade Score (pt.)	Number of Churnings	Mean Brine Concentration (%)	Mean Grade Score (pt.)
< 4·00	1	3·60	93·00	..	..	..	..	..	..
4·00– 5·49	6	4·66	92·89	4	4·65	92·38	3	4·61	92·00
5·50– 6·99	4	6·45	92·50	3	6·88	92·00	2	6·35	92·00
7·00– 8·49	4	7·15	92·56	2	7·77	91·38	1	7·88	91·00
8·50– 9·99	4	9·24	92·13	3	9·27	91·33	2	8·98	91·25
10·00–11·49	2	10·22	92·00	..	..	..	..	..	..
11·50–12·99	..	..	..	..	..	..	1	12·40	91·00

(b) Levels of Salting

(1) *Laboratory Manufacture.*—Details of brine concentrations and grade scores of small-scale laboratory churnings are given in Table 2 and Figures 1-3. As the influence of salt content on the perception of taint could be dependent on the initial quantity of tainting fraction present in the butter, grade scores were analysed according to the grade of the related unsalted churning.

Seven series of churnings were prepared from butter which scored 93 pt. as unsalted. At brine concentrations below 5·0 per cent., four churnings remained true-to-grade, two lost ¼ pt. and one decreased in quality by ½ pt. In two series, butter remained choice grade until a brine concentration of 6·4 per cent. was reached.

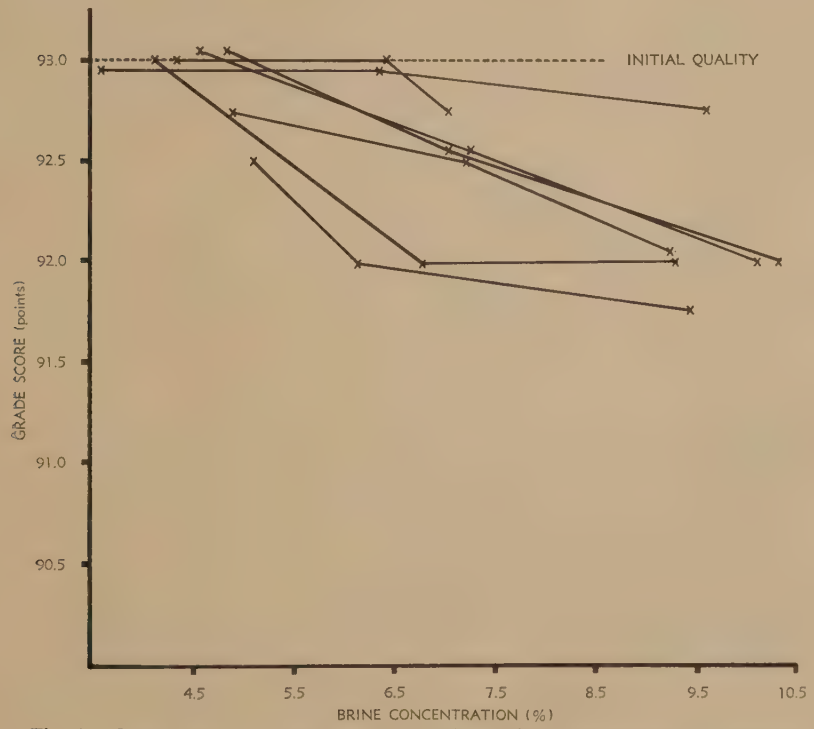

Fig. 1.—Grade scores of butters salted at various brine concentrations. (Unsalted initial quality 93 points.)

With butter which scored 92½ pt. as unsalted, a similar true-to-grade pattern was found. Below a brine concentration of 5·5 per cent., three of the four series manufactured lost only ¼ pt. or less, while the fourth sample scored 91½ pt., a loss of 1 pt.

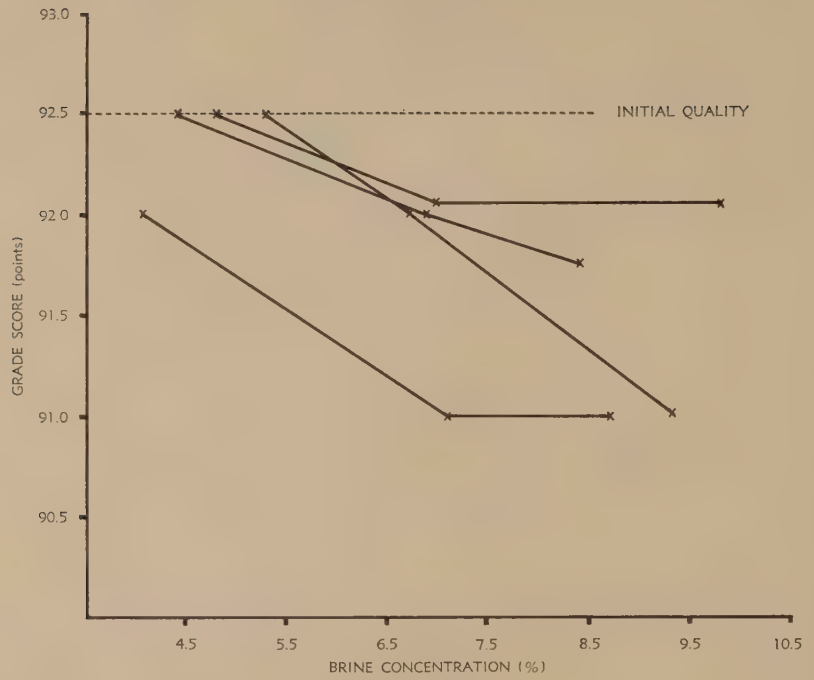

Fig. 2.—Grade scores of butters salted at various brine concentrations. (Unsalted initial quality 92.5 points.)

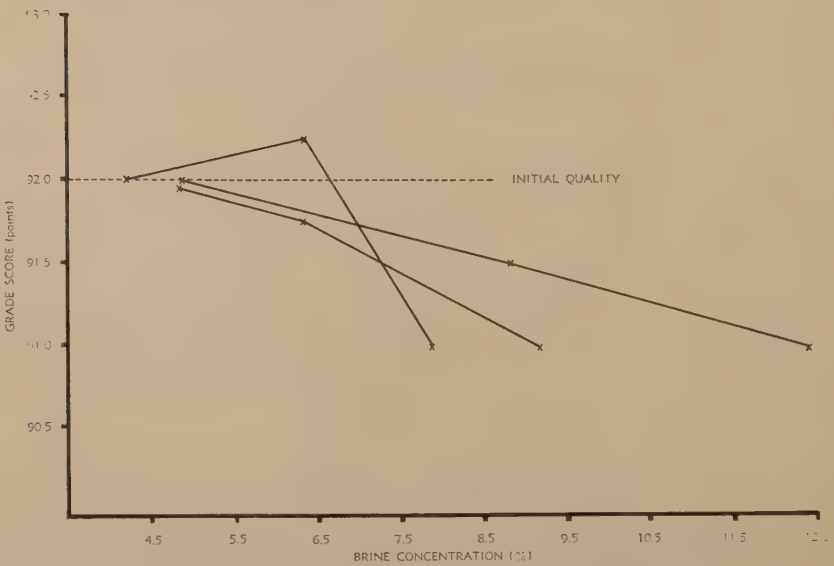

Fig. 3.—Grade scores of butters salted at various brine concentrations. (Unsalted initial quality 92 points.)

Only three series of butters were manufactured from butter grain which scored 92 pt. in an unsalted condition. Each churning retained its grade score at its original level at brine concentrations below 5·0 per cent., and one pat actually improved its score by ¼ pt. at a brine level of 6·3 per cent.

Results of the grade scores of laboratory churnings and commercial manufacture from identical butter grain salted at similar brine concentrations are listed in Table 3 and indicate a satisfactory comparison.

TABLE 3

COMPARATIVE GRADE SCORE OF LABORATORY AND COMMERCIAL BUTTERS SALTED AT "NORMAL" LEVEL

Unsalted		Salted			
Grade (pt.)	Trial No.	Laboratory Manufacture		Commercial Manufacture	
		Grade (pt.)	Brine Concentration (%)	Grade (pt.)	Brine Concentration (%)
93	9	92·75	9·59	92·5	8·85
	11	92	9·24	92	10·82
	6	91·75	9·43	92	10·44
	14	92	10·33	92	10·60
92·5	4	91	9·32	91	9·14
	5	91·75	8·42	91·75	8·20
	7	92	9·80	92	9·30
Mean 92·79	..	91·83	9·45	91·89	9·62

(2) *Commercial Manufacture.*—Results of trial churnings manufactured in the three commercial factories and of 1 lb print samples prepared in the patting plant are shown in Table 4 and Figures 4-5. It was not possible with this series of churnings to prepare samples of unsalted butter for comparison.

As with laboratory trials, it was noted with butters of low brine concentration that the majority of churnings maintained their initial grade score up to a brine concentration of 5·0-5·5 per cent. Deterioration in quality for individual series, however, was variable. Several churnings maintained their initial grade with brine concentrations up to 9·5 per cent.

At Factories A and B, where sufficient churnings were available in each brine range to permit comparisons, a decrease in brine concentration from a normal level to a low level improved the grade score by an average of 0·25 and 0·54 pt. respectively. When the salt content was reduced to a very low level, butter quality in comparison with the normal grade score was increased by 0·83 and 0·61 pt. respectively.

TABLE 4

MEAN GRADE SCORE OF BUTTERS SALTED AT DIFFERENT LEVELS (COMMERCIAL MANUFACTURE)

Brine Concentration Range (%)	Factory A			Factory B			Factory C		
	Number of Churnings	Mean Brine Concentration (%)	Mean Grade Score (pt.)	Number of Churnings	Mean Brine Concentration (%)	Mean Grade Score (pt.)	Number of Churnings	Mean Brine Concentration (%)	Mean Grade Score (pt.)
< 4·00	..	..	..	..	..	..	1	3·85	93·00
4·00– 5·49	1	5·03	93·00	5	4·65	92·50	1	4·46	92·00
5·50– 6·99	3	6·37	92·42	7	6·23	92·43	..	..	..
7·00– 8·49	3	8·27	92·00	6	7·70	92·21	3	7·81	92·00
8·50– 9·99	3	9·42	92·17	7	9·05	91·89	1	9·62	92·50
10·00–11·49	2	10·83	92·00	1	10·13	91·75	..	..	..
11·50–12·99	..	..	..	..	..	..	..	..	..
13·00–14·49	3	14·00*	91·67	8	14·00*	91·38	2	14·00*	91·50

* Brine concentration estimated on basis of 2·21 per cent. salt in a butter of 15·80 per cent. moisture.

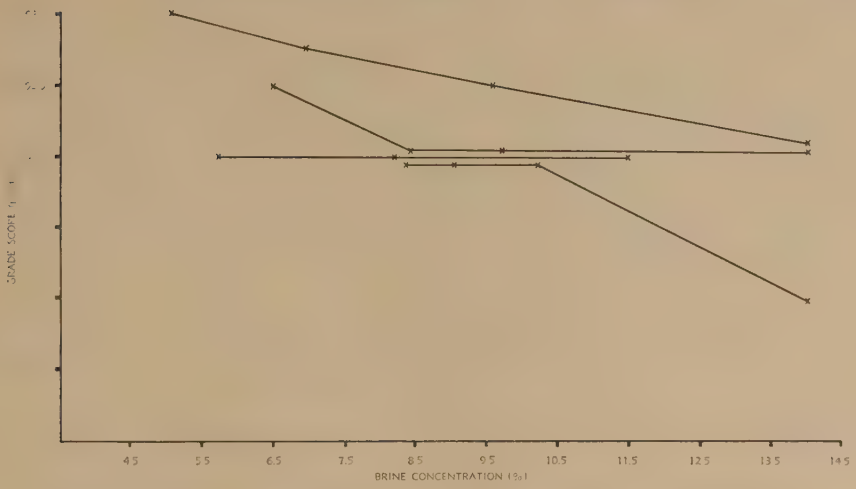

Fig. 4.—Grade scores of butters from Factory A salted at various brine concentrations.

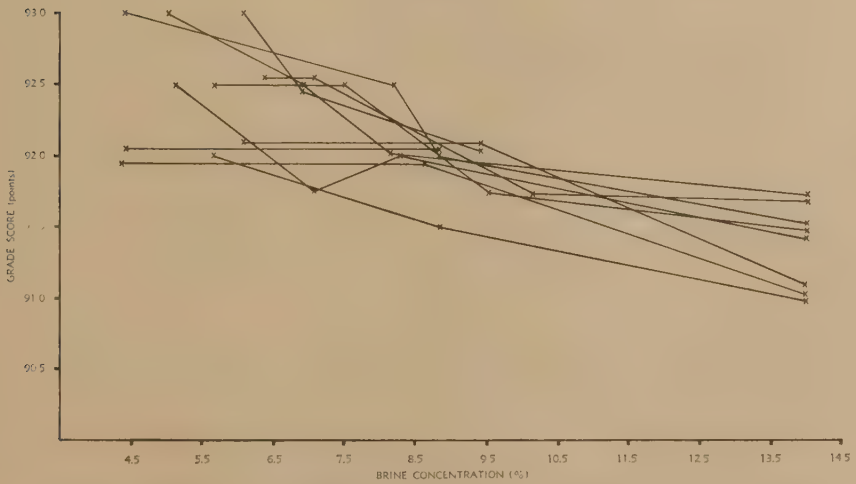

Fig. 5.—Grade scores of butters from Factory B salted at various brine concentrations.

The influence on butter quality of the higher brine concentrations of 14·0 per cent. provided in butters standardized and processed in the Abel vacuum plasticizers for local sale was similar to that obtained at the lower levels. Butters of normal brine concentration (9·5 per cent.) lost approximately ½ pt. when the salt content was increased to this higher level. With butters where initial brine concentrations were low, losses of the order of 1 pt. were shown to occur.

All samples of commercially manufactured butters had a satisfactory distribution of moisture.

IV. DISCUSSION

Several methods of control have been proposed for the reduction of weed taints in both cream and butter (Conochie 1950; McDowall 1953; Major 1960). These recommendations, however, have limited application under Queensland conditions, where the infestation of grazing areas with tainting weeds is severe, the quantities of weed-tainted cream received by a factory are considerable, the supply of high-acid creams necessitates high intensity processing treatments, and detection of weed taints in fresh cream by the conventional tasting methods is difficult.

This investigation has demonstrated that where cream is strictly graded and the subsequent butter is salted at a brine concentration of 5·0 per cent. or lower, choice quality can be obtained even if small quantities of weed-tainting substances are present in the raw cream. However, as the financial returns at present received for first quality butter are not markedly lower than those obtainable for choice quality, it would appear there is no direct economic advantage in supplying butter free from these taints in the weedy season.

From a quality consideration, there is also merit in reducing the brine concentration from the high level of 14·0 per cent. normally aimed for in plasticized butter pats when initial butter quality is of the order of 92 pt. Here also economic considerations influence the adoption of lower salting practices, as at present a similar price is obtainable for butters of 90 pt. quality and higher sold on the domestic market. Since retail experience shows consumers are able to detect the increased taint evident in weed-affected butters when brine concentrations are high, a true economic analysis is difficult unless some measure of any reduction in sales volume during this weed season is available.

Where low brine concentrations are sought, it is essential that moisture content be maintained at the maximum legal limit to enable the largest amount of salt consistent with the desired brine concentration to be added.

V. ACKNOWLEDGEMENTS

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TREATMENT OF BUTTER WASH WATER WITH ULTRA-VIOLET LIGHT

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SUMMARY

Tests of the effectiveness of sterilization of butter wash water by the use of ultra-violet light showed that, provided the water was clean, a 99 per cent. bacterial destruction was obtained; with cloudy water the destruction was less than 90 per cent. The quartz tube and reflector need cleaning at intervals of 1-2 months, depending on the cleanliness of the water. No off-flavours in butter could be attributed to the treatment. Corrosion of factory equipment was less than with chlorine-treated water. Modifications in the installation of the non-automatic model are suggested and costs of operation are given.

I. INTRODUCTION

Since the bactericidal action of sunlight was shown by Downs and Blunt in 1878 to be associated with the short-waved ultra-violet rays, the effects of wavelength and energy of radiation on bacteria have been studied by many workers.

The effectiveness of sterilization of water by ultra-violet energy depends primarily on the wavelength and intensity and exposure time of the radiant energy; it is at a maximum at a wavelength of 2600Å and falls almost to zero at 3200Å (Luckiesh 1946).

Ultra-violet rays lack penetrative power and are obstructed by dirt and water; hence water to be treated should be as free as possible from suspended material. It was also shown by Luckiesh and Holladay (1944) that the rate of disinfection of a water depends upon the turbidity and absorption coefficient of the water. They used lamps emitting 25–30 per cent. of their energy at a wavelength of 2537Å to investigate the penetration of ultra-violet light into various waters, and used parabolic reflectors to effect economy and cause the rays to strike the water at different angles.

Various other factors influencing transmission and absorption coefficients were studied by Luckiesh, Taylor, and Kerr (1944). Compounds of calcium, magnesium, sodium and aluminium in solution did not appreciably reduce the transmission, but 1 p.p.m. of iron (as ferric chloride) reduced it from 93 to 7 per cent. in a 5 in. depth of water. Reducing the temperature of the water from 25 to 4°C did not affect the transmission.

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Nelis and Lafontaine (1951), using a 200 A lamp emitting wavelengths of 2537Å, completely destroyed heavy inocula of *Escherichia coli* (13 million per ml) with rates of water flow up to 300 l. per hr. They also found that ultra-violet rays were not so effective against sporulating organisms such as *Bacillus subtilis,* or against the poliomyelitis virus. This was confirmed by Koller (1952), who found *B. subtilis* to be 5–10 times as resistant as *E. coli.*

Calculations of optical densities of various waters were made by Hoather (1955). Using a lamp with radiation at a wavelength almost entirely of 254 $m\mu$, he performed experiments designed to correlate the rate of bactericidal action with the intensity of ultra-violet radiation, calculated from the depth and optical density of the water.

Ricks *et al.* (1955), using a so-called A.R.F. ultra-violet water purifier, showed that intensities greater than 650 mw/ft^2. are effective against large populations of *E. coli.* They found that the available intensity of the lamp after burning 14 hr per day for 12 months was still greater than the limit of 650 mw/ft^2.

Most of these studies were concerned with the use of "low-pressure" mercury vapour discharge lamps, which emit ultra-violet radiation at a predominant wavelength of 2537Å (254 $m\mu$). Hoather (1955) stated that for medium and higher pressure mercury vapour lamps in quartz, the same wavelength is near the central, and probably the most important part of, the range emitted. He considered that the broad conclusions of his work with low-pressure lamps could be applied to the medium and higher pressure sources as well.

Results of tests of an ultra-violet light water sterilizer were given in test report 54C/2 (1954) issued by the National Institute for Research in Dairying (Great Britain). A high percentage kill of both *E. coli* and *B. subtilis* was recorded.

Roberts and Aldous (1949) claimed that certain types of *E. coli* may be reactivated after ultra-violet light treatment and the increase in survival level may be as much as one hundredfold. Kaudewitz (1959) suggested a lag in growth of organisms following ultra-violet light treatment.

In Queensland butter factories, water is usually treated with sodium hypochlorite to render it suitable for use in washing butter grains. Several factories are not using chlorine treatment because of the risk of chlorine or chlorphenol taints being imparted to butter, or of corrosion of the cold-water tank. This investigation was carried out to determine whether ultra-violet light could have a practical application in butter factories for the treatment of hard butter wash waters, which are prevalent in Queensland.

II. METHODS

The sterilizer used for this work was a model designed for manual rather than automatic operation; it was similar to the one tested by the National Institute for Research in Dairying (1954). A general view of the unit is shown in Figure 1. The unit consists of a horizontal cylinder 19½ in. long, 4 in. in internal diameter, and chromium-plated internally both for protection and for internal reflection. This surrounds a quartz cylinder, 1⅞ in. in external diameter and closed at one end, which contains the arc tube. The 1$\frac{1}{16}$ in. annular chamber thus formed admits water in a tangential swirl from a 1½ in. inlet pipe below to a similar outlet pipe above at the other end. A 1¼ in. diameter window is provided to allow observation of the lamp.

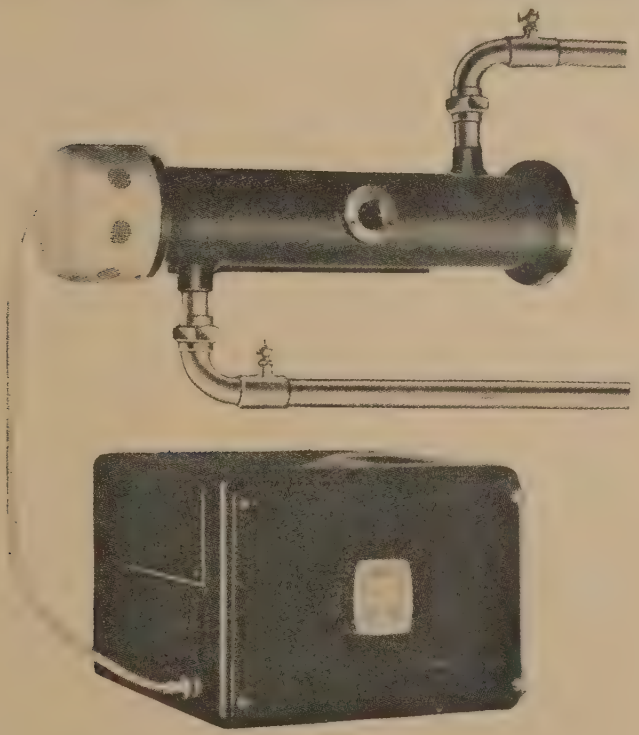

Fig. 1.—Ultra-violet light water sterilizer.

The mercury-vapour lamp in the quartz tube is of the high-pressure type and has an effective length of 9 in. and a rated consumption of 1100 W. An activating transformer supplies electric current to the arc tube, the primary current being supplied from a 230-250 V source. Starting voltage for the lamp is 450 V; this falls to 300 V for the running period. The lamp is not efficient

until 2-3 min after starting, and during this time water must be run through the unit to keep it from overheating. This water is run to waste. Rated capacity of the unit is 50-2500 gal per hr.

The unit was installed on the wall of a Queensland butter factory, on the inlet side of the cold-water tank. A more desirable position for the unit would be between the cold-water tank and the churns, in order to avoid the possibility of recontamination of the water, but as the flow rate of 4000 gal per hr through the 3 in. lines from the cold-water storage tank to the churns was greater than the rated capacity of the unit, it was placed on the intake side of the tank for purposes of the test.

The flow of water through the unit into the cold-water tank was controlled by float valves in the tank, which also shut off the flow when the tank was filled. To ensure that water would always be flowing through the unit while the current was switched on, a ½ in. by-pass line was run off from the pipeline on the outlet side of the unit, and a control valve fitted to this line. This valve was opened slightly prior to starting the unit so that the flow rate was at least 50 gal per hr. Samples of water were taken from this line for testing the efficiency of the unit.

The treated water was also sampled at three places—from the pipeline entering the top of the cold-water tank, from the cold-water line at the churn, and from a tap in the cold-water line. This was done to check on any after-contamination from the cold-water tank and pipeline between this tank and the butter churns. A cloth strainer was sometimes placed on the outlet of the cold-water line at the churn, in which case a sample was drawn from the tap in the line to check if the cloth strainer was causing after-contamination.

All samples were taken in sterilized pyrex 8 oz bottles, which were kept in iced boxes until delivered to the laboratory. Except where elsewhere stated, plating was performed in triplicate 1-3 hr after sampling. Tryptone glucose extract agar was used as the medium for total bacterial counts, the plates being incubated at 20-22°C for two days. Desoxycholate agar medium was used for counts of coliform bacteria, the plates being incubated for 24 hr at 30°C; 10 ml of treated water and 1 ml of untreated water were plated in triplicate. Presumptive coliform tests were made using single- and double-strength MacConkey broth, the tubes being incubated for two days at 30°C; 0·1 ml untreated water and 1 ml treated water were inoculated into 4 ml of single-strength broth, and 10 ml and 100 ml of treated water were inoculated into 10 ml and 100 ml respectively of double-strength broth.

The factory water supply was a mixture from a spring and a deep well. Normally it was clear but sometimes it became turbid after rain.

In order to check the possibility of quick regrowth of bacteria in the butter wash water, samples of treated and untreated water were examined 1½, 3, 5, 7 and 24 hr after sampling.

TABLE 1

TOTAL BACTERIAL COUNTS OF RAW AND TREATED WATER (PER ML)

Sampling Date	Untreated Water	Treated Water ex Sterilizer	Treated Water ex Cold Water Tank	Remarks
9.ix.58	480	26	8	
15.ix.58	8,110	11	128	
16.ix.58	190	11	247	
22.ix.58	337	1	46	
23.ix.58	140	2	29	
7.x.58	5,070	15	43	
23.xii.58	1,970	12	Not taken	New tube installed 23.xii.50
6.i.59	1,000	3	122	
13.i.59	290	260	636	Water turbid after rain
27.i.59	5,000	45* 88†	335*	Water slightly turbid after rain. Quartz tube cleaned after sampling
4.ii.59	1,210	3	86	
10.ii.59	2,370	9	78	
17.ii.59	830	16	108	
24.ii.59	1,310	9	217	
3.iii.59	2,130	29	224	
10.iii.59	1,560	15	240	
24.iii.59	1,230	19	79	
7.iv.59	980	29	65	
14.iv.59	780	2	38	Quartz tube cleaned 9.iv.59
21.iv.59	850	6	47	
28.iv.59	2,580	1	31	
5.v.59	376	1	73	
12.v.59	650	3	67	
20.v.59	780	1	22	
27.v.59	730	3	16	
2.vi.59	350	4	Not taken	
17.vi.59	530	3	42	
23.vi.59	410	4	42	
30.vi.59	710	2	58	
7.vii.59	190	3	22	
23.ix.59	700	2		Average of 12 untreated, 18 untreated
29.ix.59	2,730	22		
20.x.59	7,170	142		
22.xii.59	4,730	130		New tube installed 22.xii.59
28.xii.59	520	11		
5.i.60	1,390	1		
12.i.60	1,580	3		
19.i.60	420	2		
26.i.60	330	3		
16.ii.60	470	2		New tube installed 12.ii.60
23.ii.60	190	7		
1.iii.60	460	10		
8.iii.60	280	8		
15.iii.60	210	3		

* Before cleaning.
† After Cleaning.

III. RESULTS

(a) Total Counts

The total counts for the 18 months during which the unit was under test are listed in Table 1, which indicates that they varied from 140 to 8110 colonies per ml on the untreated water. The counts for the treated water, samples after passage through the unit, varied from 1 to 260 colonies per ml. The total counts exceeded 100 per ml on only three occasions, when the water was either turbid after rain or the tube and reflector needed cleaning. Ignoring these three results, the average plate count for the turbid waters was 16 colonies per ml, compared with an average of 1460 per ml for the raw water, i.e.. nearly a 99 per cent. destruction. It was also found that the counts on the water sampled from the cold-water tank were almost invariably higher than those on the water sampled immediately after passage through the unit. This was to be expected and indicates either contamination from the cold-water tank or growth of the surviving organisms in the cold-water tank. Hence it can be seen that the best place for the ultra-violet light unit is between the cold-water tank and the churn.

(b) Coliforms

The results of the desoxycholate agar medium counts and McConkey broth presumptive coliform tests are given in Table 2. Coliform counts in the untreated waters varied from 10 to 390 per ml, while in the treated waters the counts varied from 3 to 160 per 100 ml. The most probable number of coliform organisms per 100 ml, calculated on the results of four water samples, was much lower than the count obtained on desoxycholate agar with the same water. In all but the first sample (20.x.59), the presumptive coliform tests were negative in 10 ml water.

TABLE 2

COLIFORM TESTS ON RAW AND TREATED WATER

Date	Untreated Water (coliforms per ml on desoxycholate agar)	Treated Water (coliforms per 100 ml)	Presumptive Coliform Tests				
			Untreated Water (0·1 ml)	Treated Water			
				1 ml	10 ml	100 ml	M.P.N. 100 ml
20.x.59	378	160	+++	−−−	+++	+	
22.xii.59	28	120	+++	−−−	−−−	+	
28.xii.59	33	3	−−−	−−−	−−−	−	
5.i.60	40	3	+−−	−−−	−−−	+	
12.i.60	390	27	++−	−−−	−−−	−	
19.i.60	12	7	+−−	−−−	−−−	+	
26.i.60	19	3	+++	−−−	−−−	−	
16.ii.60	49	3	++−	−−−	−−−	+	
23.ii.60	24	17	++−	−−−	−−−	++−	0·9
1.iii.60	10	10	++−	−−−	−−−	−−−	0
8.iii.60	11	7	+−−	−−−	−−−	−−−	0
15.iii.60	15	13	+−−	−−−	−−−	−−−	0

TABLE 3

PLATE COUNTS OF TREATED AND UNTREATED WATERS AFTER HOLDING FOR VARIOUS PERIODS AFTER SAMPLING

Time after Sampling (hr)	Plate Counts per ml			
	Before U.V. Treatment		After U.V. Treatment	
	(*a*)	(*b*)	(*a*)	(*b*)
1½	485	2,840	3	11
3	560	2,595	2	12
5	690	2,955	3	28
7	1,020	2,895	2	24
24	712	2,545	2	27
Average	700	2,730	2	22

(c) Regrowth after Treatment

Table 3 gives the plate counts of two samples of treated and untreated water held for periods of 1½, 3, 5, 7 and 24 hr after sampling to see if any reactivation of the organisms occurred during these period after ultra-violet light treatment. Although these tests were of limited numbers, the results reveal that no reactivation of growth occurs up to 24 hr after treatment.

It was observed that there was less corrosion of the cold-water tank with ultra-violet light treatment than with chlorinated water. No off-flavours in the butter could be attributed to the treatment.

The quartz tube and reflector require periodic cleaning to maintain efficiency, the frequency depending on the cleanliness of the water. Cleaning at intervals of one to two months appears to be satisfactory, as reflected by the total counts.

IV. DISCUSSION

Best use of the ultra-violet light unit can be made by installing it between the cold-water tank and the churns. If the rate of flow of the cold water is greater than 2500 gal per hr, two units placed in parallel would be satisfactory. An alternative but possibly more costly method of installation with the higher rate of water flow would be to use one unit to sterilize the water leaving the cold-water tank, and to have a balance tank installed between the ultra-violet light unit and the churns. This tank should hold enough water to wash one churning of butter. Provided the tank is sterilized each day before use, no contamination of the wash water should occur.

In the non-automatic model, the following precautions are necessary:—

(1) The water should not become too hot, as this may cause the tube to blow. This can be prevented by the installation of the small "bleeder" line mentioned previously to ensure continuous flow of water through the unit, and by the incorporation of a thermostat.

(2) The unit should be switched on 3-5 min before water is required. A solenoid valve fitted to the small "bleeder" line ensures that no water is run to waste while the unit is not in operation.

(3) Sterilized water should not run to waste unnecessarily. The solenoid valve can also be used to keep water flowing through the unit while the arc tube is reaching full bactericidal efficiency.

The routine operation of the unit is as follows:—

(1) Five minutes before wash water is needed, switch on the unit, thereby opening the solenoid valve on the "bleeder" line. This ensures that only a little water is lost during the warm-up period.

(2) When the wash water is required, open the valve at the churn and run the cold, treated water into the churn.

(3) Turn off this valve when sufficient water is in the churn and switch off the unit to avoid waste of electricity and cold water.

If too much refrigeration is being lost by the flow of water through the "bleeder" line, a small line and a pump can be used to pump this water back to the cold-water tank.

A valve in the line between the unit and the "bleeder" line can be turned off overnight to prevent contamination of the treated water between the unit and the churns.

These precautions apply only to the manually operated unit. They are unnecessary with the fully automatic model which is designed to cut off the flow of water or electric current or both if operating conditions for either become disrupted.

The operational costs for water treatment depend largely on the life given by each tube, the replacement cost of which is £45. A warranty of 1000 hours' use is given, but reports from other users suggest that longer periods than this can be expected. In these trials the usual life of each tube was only 600-700 hr. If 1000 hr is taken as the expected life of the tube, the replacement cost is 10·8d. per hr. Assuming a warm-up period of 4 min and a churn-filling time of 6 min per churn at a rate of flow of 4000 gal of water per hr through two units in parallel as outlined above, the replacement cost is then 3·6d. per churning. Electricity charges vary from place to place, but assuming a charge of 3d. per unit, operating costs for two units for 10 min would be 1·2d., giving a total cost (replacement tube and running costs) of approximately 4·8d. per churning of butter. Obviously, the longer the life of the tube the lower the cost, and the lower the rate of water flow to the churn, the higher the operating costs.

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TECHNICAL NOTES

INSECTICIDAL CONTROL OF LEAF-MINER IN TOBACCO

The tobacco leaf-miner, *Gnorimoschema operculella* (Zell.), frequently occurs as a serious pest of tobacco in Queensland. Before the advent of DDT, larvae of this insect were partially controlled by the use of moth-proof covers in the seedbed and lead arsenate dusts in the field (Atherton 1936). Smith (1952) recorded the value of DDT in controlling leaf-miner in both seedbed and field, and further trials (Smith 1955 and 1960) demonstrated the extent to which dieldrin and endrin suppressed this pest.

During the tobacco seasons of 1957 to 1960, large populations of leaf-miner were present in the tobacco areas of North Queensland. Field spraying generally did not provide adequate plant coverage, and many farmers failed to achieve satisfactory control of this pest.

Three screening trials were carried out against leaf-miner larvae during the 1959-60 season at Mareeba (November 18–December 2), Parada (December 15-29) and Paddy's Green (January 11-25). The randomized block layouts, with a plot size of 10 plants in a row, were respectively 10 x 4, 8 x 4 and 8 x 4.

The following insecticides, at strengths (active ingredient) given in Figure 1, were applied with a knapsack as complete cover sprays:

DDT.—An emulsion concentrate containing 25 per cent. w/v *p.p'* isomer.

Diazinon.—An emulsifiable concentrate containing 20 per cent. w/v active ingredient.

Endrin.—An emulsifiable concentrate containing 20 per cent. w/v active ingredient.

Lindane.—An emulsifiable concentrate containing 16 per cent. w/v gamma isomer.

Methoxychlor.—An emulsifiable concentrate containing 22·5 per cent. w/v active ingredient.

Sevin.—A dispersible powder containing 50 per cent. w/w active ingredient.

"Telodrin" (WL1650).—An emulsifiable concentrate containing 20 per cent. w/v octachloro-tetrahydro-methanophthalan.

Thiodan.—An emulsifiable concentrate containing 20 per cent. w/v active ingredient.

Counts were made of living larval instars present in a leaf removed from each of the 10 plants per plot. Five samples, pretreatment and 1, 3, 7 and 14 days after treatment, were taken from the lower five leaves left after priming; leaves were taken progressively up the plant one position higher from one plant to the next, repeating the sequence for the second five plants per plot.

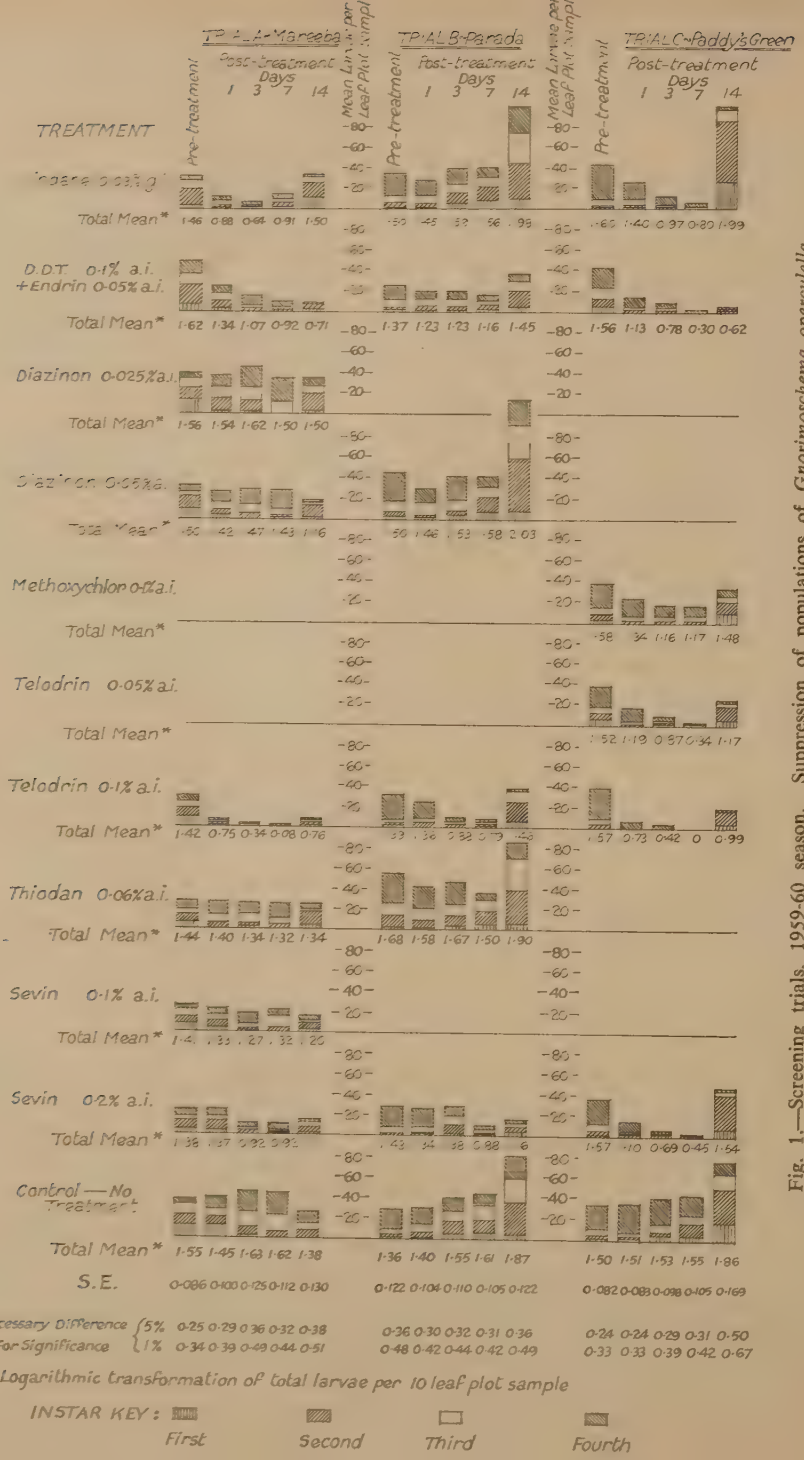

Fig. 1.—Screening trials, 1959-60 season. Suppression of populations of *Gnorimoschema operculella*.

Results are represented in Figure 1. "Telodrin" 0·1 per cent. was the most efficacious in killing larvae in all instars and in suppressing established infestations, but did not provide the residual protection afforded by the standard DDT/endrin treatment. A visible residue was associated with the use of the dispersible powder, sevin. These results, and experience which indicated that "Telodrin" can be phytotoxic to young tobacco plants, are the basis for the supplementary recommendation that, as "Telodrin" kills leaf-miner more quickly than standard recommendations, it may be of special value as a spot treatment for leaf-miner should high activity be suspected or evident (Smith and Saunders 1961).

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EFFECT OF TIMBER AND FIBREBOARD CASES ON RIND INJURIES TO LATE VALENCIA ORANGES DURING TRANSPORT BY RAIL

A limiting factor in the successful transport or storage of citrus fruits is the high incidence of green mould (*Penicillium digitatum*). It has been demonstrated by Bates (1933, 1936) that punctures or scratches small enough to rupture an oil gland are sufficient to permit infection. A method for the detection of small injuries was developed by Roistacher, Klotz, and Eakes (1956). They found that immersion of the fruit in low concentrations of 235 triphenyl tetrazolium chloride resulted in injuries appearing as clearly defined red-stained areas which could be easily counted when the fruit was examined through a stereo microscope.

As a result of the development in Australia of the fibreboard container for fruit and vegetable transport, a small trial was carried out in 1956 to determine whether transport in these containers would result in fewer injuries to the fruit, thus reducing their susceptibility to mould infection. The fibreboard container used was an experimental type, since replaced by a 2-piece telescopic type.

Methods and Materials

Fruit for the experiment was obtained from a citrus grower in the Gayndah district and consisted of oranges of the Late Valencia variety taken from the packing-shed after having been subjected to normal harvesting treatments. The treatments used were as follows:

(1) Control.

(2) Fruit packed in timber cases.

(3) Fruit packed in fibreboard cases.

The control fruit consisted of seven replicates each of 30 fruit of uniform size, taken at random from the grading machine, packed in cotton wool and carried carefully to Brisbane by motor vehicle so as to minimize injuries. Treatments (2) and (3) consisted of full cases and cartons of uniformly sized fruit packed in the normal commercial manner for the fresh fruit market. After packing, the cases were taken by road to the railway siding and railed to Brisbane, where each case was sampled. The sample consisted of 30 fruit per case, 20 of which were taken from layers adjacent to the walls of the container and the remaining 10 from interior layers in the containers. Each fruit from each sample was marked with three circles of 1 in. dia. by Indian ink—one circle at the blossom end, one at the stem end, and the third at random on the equator of the fruit. The samples were then separately immersed in a 0·05 per cent. aqueous solution of 2,3,5 triphenyl tetrazolium chloride for 20-24 hr, when they were removed and the total number of injuries per fruit in the three marked circles counted by observation through a stereo microscope.

Results and Discussion

The results are summarized in the following table:—

Average Number of Injuries per Fruit

Treatment	*Mean*
Control	24·4
Case	26·5
Carton	24·7
p 1·0%	11·4
p 5·0%	8·3

No significant differences were found to exist between treatments. This is in accord with the results of Roistacher, Klotz, and Eakes (1956), who found that there was little or no increase in the number of stainable wounds during the hauling and the subsequent standing period. In unpublished work by the authors, it has been shown that there is a large increase in injury during picking, brushing and grading, and it appears that infection occurs as a result of these injuries rather than from injuries during transport.

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